



Abstracts

4th International Congress on
Construction History

3-7 July 2012

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Cover :

Cruyl Lievin, Preparatory drawing, pen and ink, view of the Pont Royal construction site, 1686. Signed and labeled:
Liv: Cruyl auditer delineavit mense Octobri 1686 - Four or eight horse mill to pump water with a scoop.
Wheel of [missing] diameter. Heisser © Cecilia / Nationalmuseum, Stockholm.

Tuesday 3 July, 13:00-16:15 MALAQUAIS SITE

13:00-14:00 Registration-Welcome [Palais des Etudes]

14:30-15:15 Introduction [Amphi Binet]

15:15-16:15 Keynote Lecture [Amphi Binet]

Dominique Barjot

Université Paris-Sorbonne, France

Why Was the World Construction Industry Dominated by European Majors [Late 19th-Early 21st Centuries]?

The construction industry [in the English sense] constitutes a strategic sector in the world economy, particularly concerning employment. Until 2007, the most important firms were European. This was certainly the case in the Building and Civil Engineering sectors. In 2006, the top five was constituted by Vinci [France], Bouygues [France], Hochtief AG [Germany], Grupo ACS [Spain] and Bechtel [USA]. Even if, in 2010, China Railways Construction Corp. Ltd and China Railways Group Ltd passed respectively to the first and second place, Vinci, Grupo ACS, Bouygues, Hochtief and Skanska [Sweden] remained among the top ten.

The European hegemony remained strongest in the services connected to the construction industry [property development, public utilities such as water distribution as well as electricity production, transport or distribution] and, above all, in the production and distribution of building raw materials. The European cement industry offers a typical example of advanced globalization: today, there exists a global oligopoly made up of European

dominant firms such Lafarge [France], Holcim [Switzerland], Heidelberg Cement [Germany] or Italcementi and Buzzi Unicem [Italy]. However, the distribution of building supplies constitutes also a good example of the European domination with Saint Gobain [France] and its competitors, Wolseley [United Kingdom], CRH [Ireland] and Rockwell [Denmark].

Even if the European hegemony doesn't exclude spectacular failures [Philipp Holzmann AG bankruptcy in 2002 or, more recently, the financial crisis of Spanish majors], it is interesting to analyze the cyclical or structural reasons for this global European success: What is the part played respectively by technical innovation and by trade and financial strategies? What is the part played respectively by entrepreneurs, engineers and also workers? What is the part played respectively by specifically European practices versus those resulting from technological or managerial transfers, notably from the USA or Japan?

Sessions

Tuesday 3 July, 17:00-19:00 MALAQUAIS SITE

401. Construction History, Epistemology & Historiography

404. Architectural & Structural Design 1

411. Transfer of Knowledge, Colonial Situations 1

415. Craftsmanship, Gender, Individuals & Communities

420. The Real Estate Market, The Cost of Construction

423. Brick & Tile

440. Industrialization & Rationalization

401. Construction History, Epistemology & Historiography

Chair : Linda Clarke, University of Westminster, London, UK

Knut Stegmann

Institute of Historic Building Research and Conservation, ETH Zurich, Switzerland

Analysing Historical Timber Structures – A Case Study on Ernst Gladbach [1812–1896] and His Research on the “Swiss Style”

The professor of structural theory and construction materials at the Swiss Polytechnic School in Zurich, Ernst Georg Gladbach [1812-1896], is today, still one of the overlooked protagonists of construction history. His most important works, such as *Der Schweizer Holzstyl* [1868 and 1883] or *Charakteristische Holzbauten der Schweiz* [1893] have been mainly regarded as templates for the internationally recognised motif of the “Swiss Style,” especially because of their painterly manner of representation. Though, the artistic presentation and contextualisation of Gladbach’s research on historical timber structures accords to his concept of the “researcher artist,” which he himself practiced. This paper illuminates more precisely Gladbach’s methods of analysis, documentation and presentation of historic timber constructions and demonstrates its connection to contemporary research and, in particular, to the teaching at the Swiss Polytechnic School.

João Mascarenhas-Mateus

CES – University of Coimbra, Portugal

Ethnographic Studies and Their Contribution to Construction History in Portugal

The classification schemas of historical construction processes in Portugal are established in important ethnographic studies, which have been undertaken since the end of the 19th century. In works by figures such as Leite de Vasconcelos [1858-1941] and Rocha Peixoto [1868-1909] we can find an extensive mapping of the relationship between material resources, social traditions and construction technology throughout the country. During the 20th century, this body of research was developed by other scholars such as Orlando Ribeiro [1911-1997], who applied the Human Geography methodology to establish the first clear distinction between the stone culture of the North, and the earth culture of the South, integrating them in a universal context. This paper shows the importance of these studies to the establishment of a comprehensive view of Construction History in Portugal and highlights research areas opened up by such seminal works.

Torsten Meyer

Institute of Historic Building Research and Conservation, ETH Zurich, Switzerland

The Science of Building as a Polytechnic Discipline in the 19th Century

In the 19th century, the process of scientification initiated within polytechnic schools transformed and enriched contemporary knowledge on building. The genre of building textbooks written under the aegis of these schools illuminates this development most clearly. This paper focuses on the genre and its historical context; aiming to outline principally the emergence and relevance of the constitutive discursive process of “historicisation,” and to briefly outline the nature of its parallel process, “economisation.” The central thesis of the paper is that the process of “historicisation” can be considered as evidence of a method or a theory of invention.

Sascha Roesler

ETH Zurich, Switzerland

Architectural Anthropology: A Knowledge-Based Approach

In the discipline of architecture to date, hardly any approaches exist to integrate into architectural education knowledge of construction as it is found in vernacular and informal building. The following remarks are intended as a plea for the establishment of a new academic discipline that comprehensively addresses such vernacular building traditions, commonly referred to as “architecture without architects” [Rudofsky 1964]. The discipline will be entitled “architectural anthropology”; subject matter of this discipline would primarily consist of domestic, non-European building phenomena. Architectural anthropology comprises an interdisciplinary field of knowledge, in which architects – as well as anthropologists – play a crucial role. The following considerations deal only with the [possible] contribution of architects to this new discipline.

404. Architectural & Structural Design 1

Chair: Enrique Rabasa Díaz, Universidad Politécnica de Madrid, Spain

Richard A. Etlin

School of Architecture, Planning, and Preservation, University of Maryland, College Park, MD, USA

Toward an Iconography of Stereotomy

Since the history of art has been filled with symbolic meaning, there is no reason to imagine that stereotomic vaulting would have been exempt from the universal human tendency to assign religious, political, and cultural significance to its forms. Most of the paper is devoted to symbolism of Christ and the Evangelists and/or references to Solomon’s Temple as found in French Romanesque architecture: *trompes* carrying octagonal vaults in churches, the *vis de St.-Gilles* with circular window in the eponymous church in Gard, the crypt of Montmajour, and skew doorways in Angevin churches; in Valencia: the Serrano [1392-1398] and Quart [1444] city gates, the Royal Chapel [1433-1463, Santo Domingo Convent], and the Cathedral. The paper ends with a brief discussion of Philibert Delorme’s Hôtel Bullioud [1536], Lyon, considered as a purposeful creation of a Roman ruin, with references to pagan and Christian antiquity, as well as to French Romanesque antecedents.

María Antón Barco, Eva J. Rodríguez Romero, Juan Tejela Juez

CEU San Pablo University, Institute of Technology [EPS], Madrid, Spain

Builders’ Inventiveness in Madrid’s Baroque Convents: Construction Invariables

This research focuses on the constructive and design invariables recurrent in Madrid’s Baroque religious buildings. The study focuses on two representative examples: the Convent of the Holy Sacrament, known as Sacramento and the Convent of the Immaculate Conception, known as Las Gongoras. These invariables can be found by analyzing the architectural volumes, their spaces, geometrical traces, building techniques and construction materials. Throughout this analysis, the manner in which the city takes shape can be easily understood. The main sources of investigation have been historical cartography and pictures, construction treatises and similar architectural projects designed by the same architects who constructed these two examples.

Dominic Boulerice

York University, Toronto, ON, Canada

The Narthex Vaults of the Church of Saint-Germain-l’Auxerrois in Paris

Late mediaeval builders of the Holy Roman Empire, who favoured figured vaults, made use of preparatory drawings combining ground plans and rib projections [*Bogenastragung*] to devise them. In addition, they employed the so-called method of the Principal Arch [*Prinzipalbogenmodell*] to give every rib the same curvature. By rationalizing their constructive process they made stone-cutting more efficient. No documentary evidence attests to the use of these techniques to design and to erect figured vaults in France. Although French builders most probably had recourse to working drawings, the *Prinzipalbogen* method has yet to be proven. In order to find out, I surveyed the geometry of the stellar vaults of the porch of the church of Saint-Germain-l’Auxerrois in Paris. In this paper, I present the results of my analyses and speculate on the design and the erection processes used to build the stellar vaults of the western porch of the Parisian church.

James W.P. Campbell

University of Cambridge, UK

The First Complete List of All the Models Made for the Construction of St. Paul’s Cathedral, London 1675-1720

It is commonly assumed that there are only two models for St. Paul’s Cathedral [built between 1675 and 1720]. By careful re-examination of the surviving building accounts, this paper provides details of all the models, which were made during the period of construction. By so doing, it clearly shows the crucial part played by architectural models in the design process. It also shows the extraordinary range of materials from which the models were made and gives a clear idea of their different sizes and functions. The paper is accompanied by a complete list of references to models in the archives, which will hopefully be of use to future researchers. The models for St. Paul’s provide an invaluable insight into the working practice of a design office in the late 17th century, but the practices probably differed little from those used in the construction of the gothic cathedrals centuries before.

411. Transfer of Knowledge, Colonial Situations 1

Chair: **Hélène Vacher**, ENSA de Nancy, France

Benjamin Ibarra-Sevilla

School of Architecture, University of Minnesota, MN, USA

Transmission of Building Technology from Europe to the Americas: Underlying Geometry and Stereotomy Studies of Three Ribbed Vaults Constructed in Mexico between 1535 and 1575

The churches of Santo Domingo Yanhuitlán, San Pedro y San Pablo Teposcolula and San Juan Bautista Coixtlahuaca, located in the region of La Mixteca, are monumental works of Mexican architecture. They are testimony of the ambitions materialized by the motivations of a new-forming nation. Elegant ribbed vaults constructed with geometric rigor and sophisticated stereotomic solutions cover these 16th century churches. The Mixtec natives hands carved the vaults pieces and constructed the buildings quickly mastering the technology brought from Europe. The extent to which these indigenous hands impacted the systems of production and the technique itself always emerges as a question when examining this type of building. By analyzing the vaults using digital technology and showing solutions utilized in the construction of the vaults, this paper aims to provide information that reveals the transmission of building technology that occurred during that agitated period of the history of Mexican architecture.

Randall Bird

School of Architecture and Planning, University of the Witwatersrand, Johannesburg, South Africa

The Transformation of Architecture and Construction Technology of the Merina Kingdom in Highlands Madagascar, 1820-1880

This paper examines the incorporation of European architectural forms and construction techniques into the palace complex, known as the Rova, in the Merina [the Merina inhabited the central highlands of Madagascar] royal capital of Antananarivo, Madagascar from 1820 to 1860. During this 40-year period in Malagasy history, Merina sovereigns established close relationships with carpenters from Mauritius and France, and artisans from the London Missionary Society, who introduced new building types, construction techniques and design principles to the island. These architectural transformations have generally been attributed to a unilateral process of European introductions with little reference to questions centered on the dynamics

of cultural exchange and what architecture can reveal about the nature of such encounters, for example, how architectural transformations served both the Merina and Europeans.

Alexandra Quantrill

Columbia University, New York City, NY, USA

Technical Supremacy: Tropical Architecture and Technologies of the British State

In this paper I investigate the involvement of architects Maxwell Fry and Jane Drew in West African building projects supported by the British Colonial Office from the 1940s through the early 1960s. Much of the technical knowledge for this work came from studies by the Building Research Station, the first state-run research institution dedicated to problems of building and construction. There was some tension between a growing recognition of the colonial subject and the idea that technical expertise provided a neutral means of intervening in colonial territories. The very material presence of the architecture stemmed from investigations of the state, usually serving British commercial interests and subject to patterns of global trade. A form of reflexivity is visible in the technological and aesthetic transfer between the British and African contexts.

Bo-Hsun Yao, Min-Fu Hsu

Department of Architecture, National Cheng Kung University, Taiwan
The Developmental Procedure of the Traditional Architectural Woodworking Tools in Taiwan

As the Han people immigrated into Taiwan, the traditional wooden architecture inherited the styles of Fujian and Guangdong. In 1895, the Qing's ruler ceded Taiwan to Japan, initiating the 50-year colonial period. At that time, a large amount of Japanese and Western architecture was introduced in Taiwan. After World War II, the regime was returned to the Han people. Although Taiwan experienced the change in regime, its high tolerability to different ethnicity and culture and the rise of the trend of storing cultural relics led to the cultural diversity of architecture in Taiwan. The carpentry tools of the Han people were originally used to build traditional wooden architecture in Taiwan. During the Japanese colonial period, most of the craftsmen in Taiwan used both Chinese tools and Japanese tools. The cultural diversity in the use of carpentry tools still continues today.

415. Craftsmanship, Gender, Individuals & Communities

Chair: **Susan Verdi Webster**, College of William and Mary, USA

Shelley E. Roff

University of Texas at San Antonio, TX, USA

Building Construction in Medieval Spain: The Female Perspective

Contemporary studies of the medieval construction process and history of architecture have assumed an all-male labor force on the construction site and in the related building trades. Historical chronicles from the Middle Ages and their imagery support this notion, purporting the total exclusion of women from this complex industry; however, recent research has revealed that there is archival evidence pointing to the contrary. This paper presents an investigation of Spanish archives, which reveals wider acceptance of women involved in the building process in this region than previously thought. The primary sources studied document women involved in a wide range of occupations: poor women hired for manual labor, women working with their husbands and fathers in the building trades, widows continuing the workshops of their deceased husbands, and women supplying building materials for particular sites.

Nina Baker

University of Strathclyde, Glasgow, UK

Who Paints the House? Scotswomen as Housepainters and Decorators from 1820

In the early 21st century it is still considered unusual to find a woman working as a housepainter and decorator. Tradeswomen, in these most domestic of building trades, were working throughout Scotland during the 19th and 20th centuries. These were women who worked, not middle class women amateur interior decorators dabbling in the arts and crafts because it was fashionable. The historical record is compared with contemporary records of women taking paid employment in these fields and also with the strong market created in modern times by the many DIY programs on TV. The present and past involvement of women in house painting and decorating shows that the aptitude and ability exists at both the professional and amateur levels. The factual reality is compared with perception and prejudice within the industry and the barriers that were and are placed in front of women wishing to do this work.

Gemma Domènech Casadevall

Catalan Institute for Cultural Heritage Research, Girona, Spain

Building Trades in Catalonia during the Modern Era: The Case of Immigration to Girona City

One of the lesser-known aspects of Catalan art history in the modern era is the social and cultural status of its craftsmen. In the light of their production, they have traditionally been considered as artisans of limited artistic background and low economic position, with the weight of the guilds behind the development of their trades. The motivation behind *Els oficis de la construcció a Girona 1419-1833* was to prove the validity of this historically accepted premise. In this study, we examined some 800 wills and post-mortem inventories of master craftsmen residing in Girona during the 16th and 17th centuries, together with the statutes and regulations of the confraternity [later known as the guild] that united them for over four centuries. After our portrait of the professional members of the building trade working during the modern era in Girona and, by extension, all over Catalonia, we now turn our attention to the role of craftsmen coming from outside the area.

Cristina González-Longo, Dimitris Theodossopoulos

Architecture, University of Edinburgh, UK

From Master Mason to Architect: James Smith's Construction Techniques at the End of 17th Century in Scotland

Colen Campbell referred to James Smith in *Vitruvius Britannicus* as the most experienced architect in Scotland. Smith started his career as a mason and worked his way up to become a leading Scottish architect at the end of 17th century, a period which saw the creation of architects' professional identity. Smith was a mason's son and spent some years in Rome training to become a priest. At his return, he worked with the leading architects and masons William Bruce and Robert Mylne in Holyrood Palace. This paper attempts to overview his career and architectural and ornamental repertoire, uncovering his construction strategies and techniques. It will analyse their origins, whether local, and the different practices when working in a variety of buildings and contexts, since he was a mason until his latest works as an architect, both in new build or when extending existing buildings.

420. The Real Estate Market, The Cost of Construction

Chair: **Albert Malaquin**, Fondation Palladio, Altarea-Cogedim, France

Virginie Mathé

Université Charles De Gaulle-Lille 3, Halma – IpeI [UMR 8164] / IRAA [USR 3155], Lille, France

How Much did Greek Temples Cost? Economic Issues of Construction in Greek Cities [4th -3rd C. B.C.]

Some cities in the ancient world made official documents public by transcribing them into stone, which is why building accounts were found in the Delphi, Epidaurus and Delos sanctuaries 4th-3rd centuries B.C. This evidence allows us to understand in what economic and financial contexts Greek cities worked on and carried out construction projects. Several issues will be discussed: Which funding sources supported the development of these out-of-the-ordinary building sites? What practices and regulations [contracts, fines, payments by installments, etc.] were used by those involved in the project [sponsors, accountants, architects, craftsmen and suppliers]? How were prices defined? Did they actually reflect the market? Was this market local, regional or Mediterranean? Finally, what was the status of this accounting data? Is it possible to exactly evaluate the cost of public construction by studying them?

Arnaldo Melo, Maria Do Carmo Ribeiro

University of Minho, Braga, Portugal

Construction Financing in Late Medieval Portuguese Towns [14th-16th c.]

Our goal is to provide answers to numerous questions regarding the different modes of construction financing in late medieval Portuguese towns from the 14th to the 16th centuries. For that purpose, we selected four approaches or perspectives: the issue as to who commissions and pays for the construction work: the king, lords or the municipality [*concelho*]; the typology and functions of the construction: military, religious or others; the identification of who contributes, and how, to finance the construction work; and lastly the modes of financing the different production costs. In order to reach our goals, we will apply a multidisciplinary methodology, crossing various types of sources, such as written, iconographic and material evidence through the use and application of specific concepts and methodologies derived from distinct fields of knowledge that usually focus on construction, such as history, archaeology and computer science.

Michela Barbot

Institutions et Dynamiques Historiques de l'Economie, Ecole Normale Supérieure de Cachan, France

Between Market and Architecture: The Role of the College of Engineers, Architects and Land Surveyors in Real Estate Pricing in 16th-18th Century Milan

This paper provides empirical evidence on mechanisms leading to real estate pricing in early modern Milan [16th-18th centuries]. More specifically, it focuses on the moment of valuation, when conventions on houses' worth become explicit through the estimate operation. Milanese appraisals and contracts in the long run show that home pricing involves three major qualitative and non-economic factors [i.e. material, social and legal factors] and implies a double degree of valuation: a valuation of objects' qualities as well as a valuation of subjects' qualities of transactions. Regarding this double mechanism, we show not only the evolution of the estimate methods, but also the role played by the *stima* [in both senses of evaluation and reputation] of the experts of the College of Engineers, Architects and Land Surveyors of Milan in evaluating houses, workshops, and flats distributed all over the urban space.

Gema Ramírez Pacheco, Federico García Erviti

Faculty of Architecture at the Polytechnic University of Madrid [ETSA UPM], Spain

María Jesús Peñalver Martínez, Juan Francisco

Maciá Sánchez

Faculty of Architecture at the Polytechnic University of Cartagena [ARQUIDE UPCT], Spain

Building Expropriation Process for the Construction of the New Dock at the Port Of Cartagena [Spain] in the 18th Century

During the 18th c., the Bourbon monarchy mandated the building of a Naval Base in the Spanish Bay of Cartagena. To do so, different actions had to be implemented on the surrounding environment in order to prepare it for the construction of the new port. One of the priorities was the transformation of the watershed of the streams that flowed into the blocked Sea of Mandarache. This was achieved through the design and building of a dam in the northern part of the city. The design of this massive construction, which would also serve to fortify the city of Cartagena, was fraught with doubt. Its proximity to the city would result

in the demolition of several buildings in the San Roque neighborhood. Therefore, the number of affected buildings and the value of the fair compensation for their expropriation would become decisive factors in determining whether or not the construction project was a viable option for the Royal Estate.

423. Brick & Tile

Chair: Lynne C. Lancaster, Ohio University, USA

Gerold Eber

Vienna University of Technology, Austria

Masonry Constructions as Built Archives: An Innovative Analytical Approach to Reconstructing the Evolution of Imperial Opus Testaceum Brickwork in Rome

Although archaeological research has long pursued the goal of using *opus testaceum* brickwork to date building structures, hardly any of the methods proposed have provided reliable results. This paper, based on the author's doctoral thesis, investigates new dating methods for *testaceum* brickwork. The prime objective of the study is to define numerical characteristics capable of providing statistical evidence for the evolution of *opus testaceum*. The study resulted in a standardized procedure for recording and evaluating antique *testaceum* brickwork that facilitates a comparison based on significant parameters. Secondly, the application of the parameters yielded evidence that helps to define a chronological pattern of determinable development in brickwork. The large group of *testaceum* structures allows broader investigation that could lead to the recording and understanding of this technique in its entirety.

Moses Jenkins

Historic Scotland and the University of Dundee, UK

Three Key Aspects of the History of Brick Construction in Scotland

This paper explores three aspects of brick construction in Scotland from the 18th and 19th centuries. These are the use of brick to line ashlar walls, the choice of brick to construct early cotton mills and various uses of the material in tenement buildings. Whilst there are many developments that have seen brick progress from a material little used in Scotland in the 17th century to one with countless applications by the end of the 19th, it will be shown that these three are of particular significance. The use of brick ashlar acted as a conduit for English craftsmen to come north and led to the establishment of permanent brickworks; the choice of brick to construct early cotton mills led to a greater sophistication in Scottish brickwork and exhibited many new technical features hitherto unknown in this country and the uses to which it was put in tenement construction allowed bricks of lesser visual quality and durability to be employed. For these reasons the three aspects discussed can be regarded as key to the development of brick construction in Scotland.

Sara Wermiel

Independent Scholar, Boston, MA, USA

Against Replication: Carved Brick at the Dawn of the Terracotta Age

Around 1879, carved brick architectural ornamentation appeared in Boston, Massachusetts – just when the American architectural terracotta industry was taking off. Both carved brick and terracotta are clay products, and they are used in the same way: as enrichment in walls. But where carved brick was a one-off product – the unique work of a carver – architectural terracotta usually was made in moulds, and thus ornaments could be economically replicated. Nevertheless, carved brick looks so much like architectural terracotta that the uninitiated usually cannot tell the difference. Why, then, did some designers opt for carved brick? This paper proposes an explanation for the brief use of carved brick in Boston, which lasted, with a couple exceptions, from 1879-1880. Influenced by British proponents of the Queen Anne style of architecture, Boston architects embraced architectural ornament, but some adhered to Ruskin's injunction against using "cast" or mechanically-produced ornament.

Miles Lewis

University of Melbourne, Australia

The Marseilles Tile

The development of tile pressing machinery in the 1840s led to the use of a variety of patterns of machine-made tile in France. Marseille was a major port for export of terracotta products and was exporting machine-made roofing tiles by about 1860. It was only later, perhaps in the early 1880s, that the Marseille manufacturers agreed upon a standardised design and established a cooperative marketing company, the Société Générale des Tuileries et Céramiques. By the 1880s, tiles of the 'Marseilles' pattern [as spelled in English] were exported not only to French possessions such as Tunisia and Algeria, but to Turkey, India, Australia, Latin America and elsewhere. Thus a tile pattern that enjoyed no special prominence in France became an international standard. In nearly all the countries that received these tiles, local manufacture ensued in conformity with the Marseilles pattern.

440. Industrialization & Rationalization

Chair: TBA

Kinda Fares

HTTP-CNAM, Paris, France

The Dismantled War: Barracks and Industrialization of Light Construction [1914-1918]

In 1918, there was much discussion of "industrializing the Front" with a better military working organization, especially adapting the Army to the organization of big industry: supervision of engineers, performance, control, hierarchy. For a year, this industrialization of war had depended on its initial model: the barracks. On the French side, a first movable barracks was presented in February 1915, by Second Lieutenant Adrian and this was adopted, along with other removable wooden models. The handling and construction of these barracks was entrusted to the Directorate of Studies and Special Material of Engineering, which had a technical section. In Vincennes, the Directorate had a Central Establishment for Special Materiel for trench warfare. In September 1916, the Minister of War granted the Directorate a Central Establishment for Barracks Materiel. Nine months later, an Establishment for Camouflage Materiel was added. Some 30,000 prefabricated barracks were built.

Vanessa Fernandez

ENSA de Toulouse / HTTP-CNAM, Paris, France

The Simplification of the Frame: Window Experiments in the Work of Le Corbusier in the 1920s

This paper deals with experiments on the modern window frame, its simplification and rationalization toward mass-production in the work of Le Corbusier between 1922 and 1930. We will see that, in spite of his view in favor of the manufacturing of different housing components and the reduction of the non-structural crafts on the construction site, Le Corbusier was not able to implement industrialized windows. He gave first importance to the industrial look of the frame, using either steel or wood, and to the standardization of all the elements that allowed freedom of composition. In the early 1930s, Le Corbusier intended to develop industrialized sliding windows in collaboration with several manufacturers, but without success. In the following years, as window technology became more accurate, he instead turned towards low-tech solutions.

Rafael Hernando De La Cuerda

School of Arch., Univ. de Alcalá ETSA-UAH, Madrid, Spain

Rationalization of Systems and Materials in Construction in the Spanish Modern Movement: Fernando Garcia Mercadal, 1921-1937

The debate on the rationalization of systems and materials in architecture and construction is a central theme in the architecture of the Modern Movement, which cannot be separated from industrial development. In Spain, even though national industry was less developed than in Germany and France, there was a strong commitment towards education, science and technique development through the Council for the Extension of Studies and Scientific Research. The Spanish Modern Movement was represented in Madrid by a rationalist architecture carried out by a group of architects born before 1900, who started working professionally between 1918 and 1923 and are known as the Generation of 25, and the group of avant-garde architects who after 1930 became the GATEPAC. Fernando García Mercadal definitely belonged to both groups and is the only one born before 1900 who signed the constitution of the GATEPAC in Zaragoza.

Leda Dimitriadi

ENSA Paris-Malaquais, France

Post-war Industrialized Construction Processes in France and Architectural Flexibility

Post-war industrialization in building construction is an economic and technical condition supported, especially in France, by a programmatic State discourse upon construction efficiency, low cost and rapidity. It is criticized technically, esthetically and ideologically, and is considered retrospectively at best as only a half-success. Yet, the most visionary architects of this period see in it the possibility of effective flexible constructions, meaning transformable buildings. However, as the problems of mechanization of construction are being specified, flexible architectural propositions resemble the different construction systems proposed by industry in asynchronous temporalities and without covering all the distance between closed prefabrication and truly open industrialization. Such asynchronies could be the indexes of the real conceptual distance between a project of construction and architectural research. Finally, by bringing forth specific technical issues, we can restate the question of industrial processes in construction and of their implication in design purposes.

Keynote Lecture

Tuesday 4 July, 9:00-10:15 MALAQUAIS SITE [AMPHI BINET]

Ledlie Klosky

Professional Engineer, United States Military Academy, West Point, NY, USA

Men of Action - French Influence on the Founding of American Civil and Military Engineering

It is difficult to overstate the debt owed by the Continental Army to the French military engineers, largely volunteers, who provided essential support during a pivotal period in history. Equally important is the influence of the French scientific approach during the growth of American engineering practice in the early 19th century. Influential engineers and educators such as Duportail, Crozet, and Mahan were educated in French schools, and the methods they learned played an important role in early American engineering and construction practice. The resulting union of the French scientific theory, British methodology, and American need resulted in a unique combination of immigrant and homegrown engineers building the new nation.

This lecture traces the beginnings of formal engineering practice and military construction in the United States from the coming of the French engineers to the establishment of the Army Corps of Engineers and West Point. Early American engineers and professors are discussed, as is the strong connection between French and American engineering education in the early 19th century. The capstone to the early growth of engineering as a discipline in the United States came with the founding of the American Society of Civil Engineers in 1852.

Sessions

Wednesday 4 July, 10:45-12:45 MALAQUAIS SITE

402. Construction History, Education & Diffusion

405. Architectural & Structural Design 2

416. Contractors

424. Structural Bricks & Tiles

432. Vaults & Stereotomy 1

436. Wood Structures 1

441. Prefabrication 1

443. Hydraulics

402. Construction History, Education & Diffusion

Chair: **Malcolm Dunkeld**, London South Bank University, UK

José Carlos Palacios Gonzalo, Sandra Cynthia

Bravo Guerrero

Universidad Politécnica de Madrid, Spain

Construction of a Pendentive Grid Crossing Vault

This paper presents an educational experience held at the Faculty of Architecture of Madrid: the construction of an authentic ribbed vault according to traditional construction methods used in the 16th century. The vault was built in the Workshop on Gothic Building Method, a subject taught in the undergraduate cycle. We think that the knowledge of these structures cannot be achieved without carrying out their physical construction. The experience that we present here is the construction of what was formerly called a grid crossing vault. This is a vault formed by a grid of orthogonal ribs, composed of a series of cross-shaped voussoirs that are joined to form an orthogonal spatial network. Therefore, a vault is composed by two types of pieces: the voussoirs of the arches and the crossings. The vault is inspired by several examples built in Spain such as the vaults of the cloister of the Monastery of San Jerónimo de Buenavista in Seville and the vaults of the header of the sacristy of the Cathedral of Seville.

Denis Zastavni

Université catholique de Louvain, Louvain-la-Neuve, Belgium

Maillart's Practices for Structural Design [ETH-Bibliothek's Virtual Exhibition]

On the occasion of the future release of the ETH-Bibliothek's virtual exhibition some time in 2012, this paper synthesizes Maillart's approaches and reasoning on the structural issue applied to concrete structures from material that has now been collected. The idea behind the exhibition is to bring researchers and ETH-Bibliothek's resources together in order to present the original documents to an interested wider public in a modern way and within a scientific context. In the specific case of Maillart's works, the focus of the virtual exhibition is primarily on a technical analysis of Maillart's structures, methods and innovations. It is in this respect perhaps that the virtual exhibition differs from others, with the difficulty of conveying it to a non-specialist audience. This contribution resumes Maillart's methods following the main chapters of the exhibition including graphic statics, simplified calculation or analysis, full-scale testing, implicitly resorting to plastic theorems and more.

Tullia Iori, Sergio Poretti

Università di Roma Tor Vergata, Italy

The Nervi System: A Model-Game to Understand

The Pier Luigi Nervi System of construction is a combination of technical solutions used to define a new way of building that is both economical and rapid. Economical because it eliminates the wooden formwork required to pour reinforced concrete, both costly and impossible to reuse, and because it reduces the costs of materials, limiting the thicknesses of the load bearing elements [thus diminishing dead loads]. Rapid because it divides the building yard into two autonomous sectors, where workers can operate in parallel: on the one hand the building site, with the excavations, foundations, pillars and all site-cast elements; on the other, the prefabrication yard, used to prepare the pieces applied to complete the structure. The pieces are small and lightweight and easy to move from the storage area to the adjacent building site. One example of the application of the system is the construction of the Palazzetto dello Sport for the Rome 1960 Olympic Games. A model-game, designed by the authors on the occasion of the Nervi exhibition held in Maxxi, National Museum of 21st Century Arts, in Rome, from December 2010 to March 2011, helps us to understand the Nervi System.

Werner Lorenz, Roland May

BTU Cottbus, Germany

CH.ESS: European Summer Schools on Construction History

The lack of degree programs in construction history motivated a group of scholars to begin work on creating a European master's program in the field. As a first step, they set up a series of European Summer Schools on Construction History [CH.ESS]. Jointly organized by universities in Brussels, Cambridge, Cottbus, Madrid, Munich and Wrocław, the first of these events took place in Cambridge in 2011. In keeping with the transdisciplinary character of construction history, the two-week course brought together students and teachers from a variety of disciplines. The experiences gained with CH.ESS could be of interest to any university teacher who is planning to set up a degree program in construction history. With that in mind, the authors [members of the central CH.ESS organising team] will end this report with some remarks about the main problems that arose in trying to teach construction history in an international and multidisciplinary context.

405. Architectural & Structural Design 2

Chair: **Anne Cormier**, Université de Montréal, Canada

Laurent Koetz

HTTP-CNAM, Paris / LHAC-ENSA de Nancy, France

Nineteenth Century Invention under Scrutiny: Louis Auguste Boileau's Frame Construction Systems of around 1850

Louis Auguste Boileau is a renowned figure in 19th century architectural historiography for his pioneering role in building iron structures. Concurrently, Boileau also produced many theoretical writings in which he promoted his own building systems in order to renew architectural shapes. The explicit reference to Gothic architecture deserves a special attention. Even though Boileau claimed a direct influence from this period, his proposed solutions hardly seem to derive from it. They rather seem to stem out from a form of hybridization drawing upon multiple influences and permeable to diverse models. The peculiarity of the systems expressed in Boileau's writings – between scientific, technical and historical imaginary – attests to the complexity of the status of the metal framework in nineteenth century architecture.

Ralph Ghoche

Columbia University, New York City, NY, USA

The Science of the Beautiful: S.C. Constant-Dufeux and the Parabola as Constructive and Symbolic Form

This paper examines 19th-century French architect Simon-Claude Constant-Dufeux's [1801-1871] fascination with the newly popularized constructive form of the parabolic arch. Constant-Dufeux's stated goal was to reconnect sensations with reason, bodily experience with abstract fact. This eclectic gamble led to the design of a very curious monument for the Admiral Dumont d'Urville that employs the parabolic shape – the curve drawn by a projectile thrown in the air – in a way that is "self-evident" to the senses while maintaining the ideality of its mathematical precision. An often overlooked facet of the 19th-century concern with technological innovation is the extent to which these novelties were integrated into symbolic and idealist logic. This paper examines the aesthetic and symbolic dimensions of technological and constructive forms in the 19th century in the hopes of challenging some of the common assumptions of that century's architectural production.

Bill Addis

Co-editor, Construction History, Cambridge, UK

The Development of Design Charts and other Graphical Calculation Tools for Use by Building and Civil Engineers up to the Early 20th Century

The use of design charts began in the 18th century with simple 2D graphs and geometric constructions used for simple calculations. In the 1780s, the third dimension was added to graphs to produce the contour map. From the early 19th century engineers began to create bespoke charts, replacing complex equations or large tables of numerical data, in order to facilitate the regular design calculations they had to do. Léon Lalanne was a pioneer in spreading their use among engineers from the 1840s. Towards the end of the century another Frenchman, Maurice d'Ocagne invented nomography, which still represents the peak of achievement in this practical art. The paper traces 19th-century developments in the engineer's use of charts and graphical calculation tools for storing and retrieving empirical data, and for encapsulating design procedures in tools that were easy and quick to use, by young and experienced engineers alike.

Ana Rodríguez García

School of Architecture, Universidad de Alcalá ETSA-UAH, Madrid, Spain

Modern Interpretations of the Vernacular Tradition in the Work of J.A. Coderch 1940-1964

José Antonio Coderch de Sentmenat [Barcelona 1913-1984], was a Team X member from its founding congress in Otterlo in 1959. He spent the first half of his career in an international context where Modernism [the Modern Movement] underwent a critical review, with a new attitude towards tradition. He received his architecture degree in 1940 and until 1964, which was a turning point in his life, in his work he tried to combine the best values of Modernism with the constructive consistency of vernacular architecture. This paper studies Coderch's modern interpretation of vernacular tradition by examining the individual value of constructive proposals used in the projects and works of this period, and also as a whole, for they belong to a school of thought that considers climatic factors and the suitability of local materials to be the path that should be followed by contemporary building.

416. Contractors

Chair: **Dominique Barjot**, Université Paris-Sorbonne, France [TBC]

Joëlle Petit

HTTP-CNAM, Paris, France

Private Archives of the 18th and 19th Centuries: Sources for the History of Marble-Working in Belgium

Even today, relatively little is known of the work of marble-masons, but owes much to the skill and knowledge of the marble-workers of French-speaking Belgium. An essential contribution to the history of marble-working is to be found in the study of the outstanding documentation from one Belgian marble-works [quarrymen and marble-masons]. The company books we have at our disposal [dispatching ledgers and account-books] come from two periods: 1769-1784 and 1843-1889. These private archives relate to the marble industry in the region of Rance, in the Hainault and provide important information as to the technical organisation of work, the technical characteristics of marbles employed, their use and destination [principally to France and England] and on the administrative management of the firm. The exceptional documentation shows the know-how and spirit of enterprise of these marble-masters. Their work provided a sizeable contribution to the architectural heritage in all of Europe.

Koen Verswijver, Inge Bertels, Ine Wouters,

Quentin Collette

Vrije Universiteit Brussel, Belgium

The Development of Belgian Ironworks in the 19th Century: Case Studies and Reflections on Sources and Historiography

During the 19th century, especially after the second Industrial Revolution, the large number of small ironworks in Belgium evolved to a small number of large companies. The introduction of steam engines, the Bessemer convertor and large machines provided sufficient power and volume for large-scale production. In Belgium, the Walloon provinces with the cities of Liège and Charleroi were the home base for heavy iron industry whereas Flanders was far less industrialized, only housing a limited number of foundries and forges. The Marcellis ironworks in Liège and the Van Aerschot workshop in Herentals are two well-known examples of such companies. Their leaders were clever industrialists who introduced, whether successful or not, small castings, machines, bridges and spans.

Maria Luiza de Freitas

Federal University of Pernambuco [UFPE], Recife, Brazil

Architecture and Reinforced Concrete in Brazil: The Action of the Largest Construction Companies in Brazil, Christiani & Nielsen and Wayss & Freytag

We investigated the development of reinforced concrete structures as one of the key drivers of the modernization of Brazilian architecture between 1920 and 1940, based on the performance of large construction companies in the country. The urban modernization was characterized by the concentration of the main modern activities in urban centers, the restructuring of cities' spaces to accommodate new workers, and changes to the perception of the environment introduced by new media, transportation means, and infrastructure. This scenario allows for us to analyze the arrival of two foreign construction companies in Brazil: Wayss & Freytag, one of the most important companies specializing in reinforced concrete systems, and Christiani & Nielsen, a Danish construction company. These firms were a true experimentation field, and consequently contributed to the formation of professionals capable of creating a new aesthetic arising from this technique in Brazil.

Javier Martinez-Gonzalez, Marta Garcia-Alonso

School of Architecture, University of Navarra, Pamplona, Spain

Building Modern Spain: Some Notes on Huarte y Cía

The construction company Huarte y Cía was created in 1927 in Pamplona, a small city of northern Spain. The creative and skilful management of Felix Huarte, its founder and president, together with the highly qualified staff of its Technical Office, made it one of the most relevant Spanish contracting firms. When Félix Huarte died in 1971, Huarte y Cía. was the head of an industrial corporation composed of 45 companies, while the Huarte family had become one of the most generous patrons of the arts and culture in Spain.

424. Structural Bricks & Tiles

Chair: **Tom F. Peters**, Lehigh University USA [TBC]

Jennifer Zessin, John Ochsendorf

Massachusetts Institute of Technology, Cambridge, MA, USA

Efficiency in Form: Thomas Jefferson's Serpentine Walls at the University of Virginia

Thomas Jefferson, founder and architect of the University of Virginia, included a number of innovative building systems in his design of the school. In particular, Jefferson designed a series of undulating brick walls, known as serpentine walls, to enclose the gardens at the University. This paper describes the history and origins of serpentine walls, as well as the development of Jefferson's walls, in order to track the transfer of technology to the United States. In addition to understanding the intent of the design, particular attention will be paid to the performance of the walls, with a cursory discussion of the effects of curvature on the lateral stability of walls. A preliminary analysis of the walls based on Jefferson's original description of the walls is included. This analysis, combined with new information regarding the history of the serpentine walls, provides a new understanding of a major work of American construction.

Esther Redondo Martínez

Department of Building Technology, Universidad Europea de Madrid, Spain

Tests on Tile Vaults in France in the 19th Century

Throughout the 19th century the construction of tile vaults experienced enormous development and the use of these vaults spread to new types of buildings, as well as to areas where they had not traditionally been constructed. In addition, cement started being used as a binder instead of plaster. In this context numerous tests were carried out on these vaults, in order to validate a construction system that was considered new for these reasons. This paper studies a series of strength tests carried out in France between 1837 and 1865, all of them on vaults of similar size and geometry, with spans between four and five m. and a rise of 1/10 of the span. This type was frequently used in the construction of industrial buildings at that time. The first test aims to measure experimentally the thrust of one of these vaults, to end a debate on whether or not tile vaults exert thrust. The tests seek to obtain the failure load of the vaults to be used in the design of similar vaults.

Nan-Wei Wu

University of Edinburgh, UK

Structural Morphology Presented on Surface Cladding: From Structural Brick to Ornamental Tile in the Westernised Far East

The determination of the surface cladding of architecture often resulted from the availability of constructive techniques and materials as well as the cultural and social perspectives that architects would like to express, while the latter element is sometimes potentially more crucial. In this paper, the skeuomorphic link between structural brick and ornamental tile for the surface cladding of construction and for buildings in the westernised Far East is the focus. The social and cultural perspectives will be considered in significant examples, since these perspectives have strongly affected this structural morphology. This practice contained the diffusion and transfer of knowledge and of political power. Several architectural projects are examined in order to illustrate how these influences have played significant roles in the cladding of constructive elements, that is walls, in the construction history of the westernised Far East.

Gemma Muñoz Soria

Universitat Politècnica de Catalunya, Spain

Load-Bearing Wall Structures in the Works of Lluís Nadal

Until the introduction of the first brick masonry standards in 1972, construction in Spain traditionally used load-bearing walls in all types of dwellings. Lluís Nadal, a Catalan architect, was one of the last architects to combine the design of dwelling interiors with load-bearing brick structures. His most significant works are the apartments at 307, Carrer Lepant [1963-1968] and 44-50, Carrer de les Tres Torres [1970-1974]. Nadal designed the interior layouts using load-bearing walls. These walls functioned to ensure the basic structural concept, strength and stability by means of structural elements and ties. The design included various nucleuses that increased the inertia of the overall construction and formed a series of spaces that, structurally, functioned independently. His work is, then, based on specific knowledge of construction processes, in which the essence of the Mediterranean provided the basis of the balance needed to posit his architectural discourse.

432. Vaults & Stereotomy 1

Chair: **Richard A. Etlin**, University of Maryland, USA

Ursula Quatember

Austrian Archaeological Institute, Vienna, Austria

Barbara Thuswaldner

Institute of History of Art, Building Archaeology and Restoration,
Department for History of Architecture and Building Archaeology,
University of Technology, Vienna, Austria

Opus revinctum in Dome and Barrel Vault Constructions in Roman Asia Minor

Building with large stone blocks, also called *opus revinctum*, was a method frequently used in the architecture of Roman Asia Minor. Vertical connections were established with dowels, horizontal joints were secured with clamps. Mortar essentially was not applied. This paper presents examples for dome and barrel vault construction carried out in this technique. Unfortunately only a few monuments have been studied in greater detail. This paper aims to present some of these examples and to discuss their design. However uniform their appearance might seem at a first glance, the underlying structural principles are surprisingly manifold: They include true dome construction as well as corbel vaulting and flat arches. Our goal is to attract attention to these monuments and the neglected questions of their structural design.

Enrique Rabasa Díaz, Miguel Ángel Alonso-Rodríguez, Tomás Gil López, Ana López-Mozo

Universidad Politécnica de Madrid, Madrid, Spain

José Calvo-López

Universidad Politécnica de Cartagena, Cartagena, Spain

Alberto Sanjurjo Álvarez

Universidad San Pablo-CEU, Madrid, Spain

The 100 Ft Vault: The Construction and Geometry of the Sala dei Baroni of the Castel Nuovo, Naples

After the conquest of the Kingdom of Naples in 1442, Alfonso V of Aragon transformed the Castel Nuovo, an old Angevin fortress in the capital, into a new palace. In addition to commissioning the well-known triumphal arch ascribed to Francesco Laurana, he ordered the Majorcan architect Guillem Sagrera to construct a number of singular spiral staircases, a rib vault behind the arch and an octagonal tierceron vault over the castle's main hall. Measuring approximately 26 m. wide, the octagonal vault may be the largest of its kind in European Gothic architecture. This has led us to prepare a specific survey of the vault, carried on by means of a laser total station, in order to determine its exact

geometry. In this paper, after an introductory section on the vault's construction, we present our analysis of the geometry and tracing methods of the vault, paying special attention to the tension between the regular, octagonal layout of the vault and Sagrera's idiosyncratic style.

Marina Šimunić Buršić

Faculty of Architecture, University of Zagreb, Croatia

Construction of Early Rib-Vaults in Croatia

The preserved early rib-vaults in Croatia belong to the period of experimentation with a new structural element, diagonal arches, which opened the path to the Gothic rib-vault. Like in other European regions, the first rib-vaults built in Croatia at the beginning of the 12th century are characterised by massive diagonal arches, rectangular in cross section. The geometry of the vaults ranges from hemispherical domes with diagonal arches to rib-groin vaults with horizontal ridges; from unusual combinations of progressive elements within traditional forms of vaulting, to the original solution of rib-groin vaults with horizontal ridges in the bell-tower in the Benedictine convent of Zadar. The construction of the vault in the Zadar bell-tower, begun in 1105 and completed by 1111, is documented by the original donor's inscriptions, which makes it one of the earliest precisely dated rib-vaults in Europe.

Alberto Sanjurjo Álvarez

Universidad CEU-San Pablo, Madrid, Spain

The Chambiges and the Construction of Vaulted Stone Spiral Staircases

Martin Chambiges, the most representative architect of the Flamboyant Gothic Style, is known as the architect of the transepts of Sens and Beauvais Cathedrals and of the main façade of the Cathedral of Troyes. In these constructions he designed and built, assisted by a group of collaborators and disciples, very singular stone spiral staircases. These are the so called *vis de Saint Gilles* with circular or polygonal plans, that may be considered real wonders from the point of view of stereotomy. This paper deals with the study of the geometry and construction of these staircases and tries to enlighten the debate about the attribution of some of his possible works.

436. Wood Structures 1

Chair: **François Fleury**, ENSA de Lyon, France

Silvia Dandria

Politecnico di Milano, Verona, Italy

Commercial Categories and Applications of Construction Timber in the Trentino-Verona Area [14th-16th Centuries]

The Adige River was one of the principal routes of the medieval and modern eras for the transport and distribution of construction timber into the east of the Po Valley. Along the upper course, rafts of logs and semi-finished wood products from Tyrol and the mountains circling Trento would come down and proceed directly towards the lowlands. It was an organized and standardized production market, both upstream and downstream, from specific institutions and commercial companies. As well as being an important center for sales and employment, the city of Verona had the role of being a trading center from which goods and timber were distributed along commercial routes toward the cities of Mantua, Ferrara and Venice. Through documents regulating production and distribution, it is possible to reconstruct a list of the selections of timber used in connection with the documented supply of materials in the construction of wooden structures of two significant historic buildings.

Giuseppe Rociola

ICAR Department, Polytechnic of Bari, Italy

Wooden Embankments in the Lagoon Territory of Capitanata between the 18th and 19th Centuries

The study concerns the analysis of the techniques of using wooden embankments dating back to the Bourbon period, between the 18th and 19th centuries to control the waters in the Capitanata territory located in Apulia [Italy] between the Gargano and the Murgia mountains and the valley of the river Ofanto. This plain is essential for the production of salt and fish in the Salpi lagoon, as well as crops, and enormous efforts were made to try to control the flooding that threatened the man-made boundaries laboriously engineered at that time. The synthesis of this commitment is summarised in the letters exchanged between technicians of the Kingdom of Naples and the designers, who tested the timber structures with the common goal of protecting the saltworks, salt basins and cultivated fields, involving the architect Luigi Vanvitelli and the engineer Carlo Afan De Rivera in a colossal reclamation project.

Anja Wünnemann, Stefan M. Holzer

Universität der Bundeswehr München, Neubiberg, Germany

Clemens Voigts

Deutsches Archäologisches Institut, Rome, Italy

Wooden 'Italian' Wide-Span Roofs of German 19th Century Theatre Buildings

Timber constructions of the 19th century have hitherto received little attention, although timber continued to be employed a lot, at least until the beginning of the last third of the century. Even for buildings exposed to a high fire hazard, such as theatres, railway stations or industrial buildings, timber was a common material. The present paper analyzes several 19th century timber roofs in Germany, with particular attention to theatre roofs with a span around or beyond 20 m. The paper focuses on the import of the Italian-type purlin roof and its assimilation into autochthonous carpentry practice in Germany.

Stephen Buonopane

Bucknell University, Lewisburg, PA, USA

Sarah Ebright

University of Wyoming, Laramie, WY, USA,

Alex Smith

Arup, New York City, NY, USA

The Timber Trusses of R.W. Smith: History, Design and Behavior

During the 1860s and 1870s, Robert W. Smith designed four timber truss types for covered bridges, and the Smith Bridge Co. became commercially successful in the Midwestern United States. Smith trusses have two overlapping systems of timber diagonal members interconnecting the chords, and, unlike many competing truss types of the time, they do not use iron for any primary structural members. Analysis of Kidd's Mill Bridge [1868] and Rinard Bridge [1876] show that Smith trusses reflect a fundamental understanding of structural behavior and design consistent with 19th century practice. Member stresses and vertical deflections are well within acceptable limits. Influence lines are used to identify members which experience force reversal under concentrated live loads and to estimate maximum live loads. Strength analysis of a typical tension member-to-chord connection shows that transverse forces and splitting cracks significantly reduce shear strength and contribute to observed failures in these connections.

441. Prefabrication 1

Chair: **Volker Wetzck**, Brandenburg University of Technology, Germany

Francis Guillemard

CNAM, Paris, France

Charles-Henri Besnard de Quelen: A Precursor of Prefabricated Construction

This French architect [1881-1946], a disciple of Anatole de Baudot and Viollet-le-Duc, expressed an early interest in construction processes. Already in 1917, he had filed a patent with the CNAM for constructing in molded concrete and foam cement. Named Chief Architect of Historic Monuments, he applied his inventions to numerous edifices such as the Saint Quentin Hospital, the National Office of Tourism on the Champs-Élysées and the Poulain Chocolate Factory in Blois.

In 1919, at the Foire de Paris, he presented a reinforced concrete house for the first time, which was, moreover, the first entirely prefabricated dwelling. His inventive contribution is evident in the building of St. Christophe de Javel Church. The edifice, entirely in reinforced concrete, is composed of molded components fabricated on the construction site and then directly integrated into the assembly of the building.

Rafael García García

Universidad Politécnica de Madrid, Spain

Concrete Meccanos: Precast Constructions after the Second World War in the Netherlands

This paper deals with prefab constructions in utility buildings in the Netherlands' reconstruction years after the Second World War. Specifically, housing and non structural or decorative elements are left out of consideration. A first analysis focuses on the state of this technique in the period but the main part is dedicated to categorize the different solutions and to analyze the most salient examples. They include self-bearing façade components, roofing elements for sheds and some singular cases of portal frames. In addition one special attention is devoted to the precast components solutions which are shown in an interesting number of cases. Finally, some considerations are made about the standardization and the kind of structures to which was applied. It is remarkable, the great inventiveness and skill showed in this technique and the singularity of some of its achievements.

Hernando Vargas

Universidad de los Andes, Bogota, Colombia

RetCel: The Development of Floor and Roof Assemblies of Precast Concrete Cells in Colombia, 1949-1989

Based on archival, primary and published sources around concrete prefabrication industry development in Colombia [1946-2006], this paper focuses on a proposed staging of this innovation and adoption experience as an outstanding case of local professional and industrial organizations offering modern building systems for an expanding market. Started in 1948, after direct observations on the Brazilian experience of open plan architecture, among other proposals for new building procedures, the Retcel patented system accumulated 40 million ft² of licensed built slabs in six countries as of 1963 when it was considered to be introduced in the United States. Colombian modern building architecture registered for decades a marked influence of this technology down to the 1984 and 1998 new seismic resistance-oriented construction codes.

Laura Greco

University of Calabria, Cosenza, Italy

The First ENI-SNAM Headquarters in San Donato Milanese: Some Features of Industrialization in Construction Techniques Applied to Office Buildings in the Post Second World War Period in Italy

This paper analyses some features of industrialization in office buildings during the post Second World War period in Italy, through the example of the first ENI-SNAM headquarters. The application of industrialization in office buildings often produced "hybrid" configurations, where inclination towards standardisation and modern techniques merged with the preservation of more traditional construction aspects. The ENI-SNAM building in San Donato Milanese [1956-1958], designed by Marcello Nizzoli and Mario Oliveri, stands out as an example. The building has a steel structure, curtain walls and prefabricated partition walls. In the office building, on one side, the attention to advanced construction processes is evident, while on the other side, the building stands out due to its curtain wall design, which proposed an original interpretation of industrialized products. In fact, the figurative features of the façade reduce industrialization, highlighting the link between architecture, figurative arts and industrial design, developed by Nizzoli.

443. Hydraulics

Chair: **Pascal Douard**, Conseil général de l'environnement et du développement durable, France

Anna Decri

Institute for the History of Material Culture [ISCUM], Genoa, Italy

The Historical Aqueduct of Genoa: Materials, Techniques and History - A Way to Know

This contribution is part of a work commissioned by the Municipality of Genoa to Iscum [Institute for the History of Material Culture] concerning the cataloging of the historical aqueduct, a significant architectural structure that extends for about 40 km. The work consists of cataloging all the constituent elements of the structure of the aqueduct [bridges, galleries, arcades and simple channels] and also includes the census of manufactured accessories for the channel, such as sluice gates, blowholes, milestones, fountains. The data collected is the result of spot investigations and bibliographic research and is managed through a database specifically developed for this purpose. This database also allows the inquiry and facilitates the cross-comparisons and the knowledge of relationships between phenomena, materials and construction techniques. This paper describes the approach used and the first results of this collaboration.

Yasuhiro Honda

Miyazaki, Japan

Keiko Nagamura, Ichiro Kobayashi

Graduate School of Science and Technology of Kumamoto University, Japan

Construction Process of the Tsujunkyo Aqueduct Bridge [1854] – A Case Study of Japanese Bridge Construction in the Edo Period

This research clarifies the construction process of the Tsujunkyo Aqueduct Bridge, constructed in 1854 in Yamato City in Japan during the Edo Period, just before the introduction of occidental technologies. This aqueduct bridge improved the agricultural situation of a small plateau where the farmers had much difficulty irrigating their rice fields. With this aqueduct bridge's large stone arch and siphon effect provided by a stone pipe, it is recognized as a representative symbol of Japanese traditional construction techniques. However, this technique has been thought a kind of miracle, and thus most researchers discuss only its technical aspects. In this context, we analyzed the official documents for the aqueduct bridge's construction and clarified the construction process. We do so from three viewpoints that are fundamental for construction projects: politics, economics, technology.

Naoto Tanaka

Center for Policy Studies, Kumamoto University, Japan

The Role of the Tsujun Irrigation Canal's Construction and Maintenance in the Creation of a Cultural Landscape [Shiraito Plateau, Kumamoto, Japan]

The Tsujun irrigation canal is an agricultural irrigation canal built in 1854 to supply water to Shiraito Plateau in Kumamoto Prefecture, Japan. Since then, the canal system has been supplying water to the terraced rice paddies on the plateau for about 160 years. In the background of the continuously used canal, there is a local rule to distribute the precious water evenly, which has been protected from the time of construction to today. This study focuses on the system and technologies and has the objective of making known the transition of operational management of the Tsujun system and its current status. Specifically, by organizing previous studies and historic records, observing the irrigation channel's structure and maintenance work by field survey and making records of the system of self-government for operation and maintenance and the many unwritten rules.

Carlo Togliani

Polytechnic University of Milan, Italy

Water Pumping Plants for Land Drainage in the Po Valley, A Case Study of The Mantua Region [1866-1940]: People, Techniques, Materials

For centuries, the area around Mantua was largely at the mercy of water's whims, of flooding and stagnant water. Traditional gravity drainage systems remained in use until the mid-19th century. It was only then that new mechanical technologies, and revolutionary new building materials and construction techniques were introduced. With Milan leading the way, Italy's major industrial cities and universities recruited leading-edge engineers and workers. Iron and reinforced concrete made a wider range of hydraulic parts possible; monumental structures were built to house the massive machinery of the thermal power stations and thermoelectric power plants [initially propelled by steam, later by diesel and electric engines]; and pumps composed of turbines, horizontal centrifugal pumps and vertical screw pumps began to be used. The Mantua region was exemplary in terms of the complexity of its hydraulic structures and the quality of the technical and architectural solutions it employed.

Sessions

Wednesday 4 July, 14:00-16:00 MALAQUAIS SITE

403. Construction History, Heritage & Restoration

406. Applied Sciences 1

413. Transfer of Knowledge, Political Initiatives

417. Organization of the Construction Site

425. Stone

433. Vaults & Stereotomy 2

444. Infrastructure & Public Works, Bridges

306. Rules & Standards, Building Regulation Compared

403. Construction History, Heritage & Restoration

Chair: **Sergej Fedorov**, Karlsruhe Institute of Technology, Germany

Ishanlosen Odiaua

Université de Paris 1, Paris, France

Abraham A. Taiwo, Rosemary Ajayi

Department of Architecture, Federal University of Technology, Akure, Nigeria

Use of Modern Materials in the Conservation of Traditional African Buildings

Africa's architectural and built heritage has adapted to, and incorporated, new technologies and materials. Most of these efforts have taken place within the informal, traditional sector, with cultural meaning serving as the basis for conservation choices. "New" materials and technologies are increasingly applied to meet the challenges of keeping African traditional architecture alive. This paper, through selected case studies, identifies the plusses and minuses of the adaptations, and discusses the challenges that the borrowing poses. It identifies the factors that contribute to the obsolescence of indigenous construction technologies and the loss of local knowledge systems. It further establishes the existing expertise for the conservation of these technologies as well as what adaptations have been made, with modern materials, in current restoration practice. It concludes with a synthesis of the dominant trends and recommends steps necessary for the emergence of African conservation expertise to ensure adequate preservation of this architecture.

Damiana Lucia Paternò

Politecnico di Milano, Italy

The Interpretation of Palladio's Building Techniques: Palazzo Chiericati and the Restorations of the 19th c.

Palazzo Chiericati represents a true 'experimental worksite' where Palladio introduced a series of formal and technological innovations, which will later become a trademark of his work and of the building tradition in the Veneto region. He created architectural elements typical of the classical culture [columns and stone-like architraves] with simple material [plaster-coated bricks and wood]. The building was completed only in the last part of the 17th century, while the first restoration dates back to the 19th century, when it was perceived as an opportunity to bring the building back to its 'original conditions,' according to the Neoclassical perspective. The construction, completion and restoration of the palazzo help us to understand how Palladio's technical

skills were interpreted and modified according to the evolution of the critical views and building traditions that had spread throughout the Veneto region over the centuries.

Tom F. Peters

Lehigh University, Bethlehem, PA, USA

Conceptual Problems in the Restoration and Adaptive Reuse of Historical Structures: The Rhaetian Railway Bridges in Switzerland

Finding a balance between visual and technical integrity in the preservation of technologically significant structures is a complex problem, especially when the objects remain in use and have to be upgraded to adapt to new uses and take modern structural codes and laws into account. The restoration of the 592 bridges of the alpine Rhaetian Railway in the mountainous Canton Graubünden in Switzerland that was built between 1898 and 1910, part of which was declared a UNESCO Heritage Landscape in 2008, provides a case study in dealing with the multiple issues involved that range from UNESCO guidelines, touristic and aesthetic requirements and corporate imagery as defined by the client to technical requirements and personal value judgment by the restorer. Theoretical consistency and conceptual clarity can provide a guideline but cannot solve the problem; subtle, creative design thinking is needed to supplement the process.

Franz Graf

Università della Svizzera Italiana and Ecole Polytechnique Fédérale de Lausanne, ENAC – IA-TSAM, Switzerland

Material History and Conservation of Contemporary Building Fabric

This essay will deal with the relationships in play between construction history and architectural design and will attempt in particular to specify what kind of construction history architects and/or historians of architecture working on existing buildings should be making use of. Can the built architectural object, a primary documentary source, also become an active component in the way we practice architecture? To what extent does the "as found" material identity of architectural objects determine maintenance, repair, renovation and restoration strategies? An historical understanding of 20th-century construction materials, methods and practice – the "material history" of contemporary building fabric – and

monographic studies on representative works provide us with the essential methodological tools we need when designing for existing structures, as well as being subjects of research relevant to modern and contemporary architecture and vital instruments for the teaching of architectural practice.

406. Applied Sciences 1

Chair: **Hermann Schlimme**, Max Planck Institute for Art History, Italy

Sara Franceschelli

Université de Lyon, ENS de Lyon, Lyon / IXXI, Rhône-Alpin Institute of Complex Systems, Lyon / Ensadlab, ENSAD, Paris, France

Antonella Mastrorilli

ENSA de Lyon, Laboratoire d'Analyse des Formes, Lyon, France
Firmitas and the Status of the Laws of Statics and Mechanics

In the interplay between the development of construction and of mechanics, and more in general of modern scientific thinking, the question about the status of *firmitas* – whether it is necessary or contingent – runs across different ages and different philosophical and scientific universes. In this paper we put into perspective this question in the context of the evolution of classical mechanics, from Enlightenment to 20th century developments. We first consider the question posed by the Berlin Academy for its competition on necessity and contingency of the laws of statics and mechanics. In the light of the independence of predictability from determinism for sensitive to initial conditions systems, we then try and evaluate the status of *firmitas* in the recent developments of digital architecture. In this field, in fact, morphological research is often based on the properties of unstable systems.

François Fleury

ENSA de Lyon, France
Some Aspects of John Wallis's Structural Mechanics

Albeit not a construction practitioner, the mathematician John Wallis [1616-1703] shows a clear interest in statics and structural mechanics in the “Mechanica: Sive, de Motu, Tractatus Geometricus.” The present contribution focuses on chapter six in the third part of the treatise. In this chapter, Propositions VII through X address a number of questions directly related to construction problems, namely the resistance needed for a simple beam, the force taken by each support of an inclined beam, the strength necessary for the supports of a statically indeterminate system, and the computation of the load carried by the individual elements of the floor nowadays referred to as the 'Serlio Floor'.

Patricia Radelet-de-Grave

Université catholique de Louvain, Louvain-la-Neuve, Belgium
Newtonian Scientists on the Relation between a Catenary Curve and an Arch Supported by its Own Weight

The role played by the problem of the catenary at the beginnings of the process of mathematization of elasticity is well known. I have already shown how important the study of this curve was for the elaboration of differential and integral calculus by Leibniz and the Bernoullis. The success of leibnizian calculus in solving this problem should have given rise to reactions from defenders of Newton's calculus of fluxions. But they'll react only seven years later. In the article we study some of those belated reactions because they are mainly concerned with the study of arches supported by their own weight.

Luc Tamborero

GSA-ENSA Paris-Malaquais, France
Curves Mastery at the Royal Academy of Architecture: The Case of Jules Hardouin-Mansart

Curves that form a vault on its underside vary according to the kind of construction techniques or geometry used. In the geometries of the Renaissance, codified in several known treatises, the intersection curves of a vault depend on the type of drawing used: their appearances are only a consequence. New methods of geometrical drawing for stonecutting were developed by the Royal Academy of Architecture to provide a new design, a new order for royal projects. With the support of scholars, such as Philippe de la Hire, who create innovative drawing techniques taught to architects and engineers of the King, the new face of the curve, this new control, allows the passage from a technique to a science. Students of De la Hire, as Amédée François Frézier, will then push the research of the curve becoming the springboard of descriptive geometry. Through studying the texts of the Royal Academy of Architecture and the constructions of Jules Hardouin-Mansart, including the vault of Arles City Hall, the church of the Invalides and the Royal Chapel of Versailles, we will understand the search for a perfectly harmonious curve.

413. Transfer of Knowledge, Political Initiatives

Chair: **Patrick Février**, Conseil général de l'environnement et du développement durable, France

Francisco Prado, María F. Vargas

Pontificia Universidad Católica de Chile, Santiago, Chile

Renato D'Alençon, Daniel Korwan, Johanna Moser

Technische Universität Berlin, Germany
Traces of Construction Following Migration: Transverse Gable; Massive Timber and Carpenters' Marks in the Houses of the 19th Century German Settlers in Southern Chile

During the immigration of German settlers in southern Chile organized by the Government between 1852 and 1875, a total of 6,952 people settled mainly along the shore of Lake Llanquihue, a region then largely unpopulated. This immigration led to the construction of a vast architectural heritage, which is recognized in the country as "German" architecture. However, it has not been clearly established to what extent the houses built by the settlers in southern Chile were influenced by the import of European models. In this work, we attempt to identify the specific influences developed by these immigrants in southern Chile. Traces of such influences are found in basic elements and building systems and architectural elements, transverse gables, massive timber and carpenters' marks, which we document and discuss in a parallel study of cases both in Chile in the mentioned areas and in the areas of origin where the emigrants lived before departure.

Martin Trautz

RWTH Aachen, Germany

Friedmar Voormann

Karlsruhe Institute of Technology, Germany
Early Iron Bridge Construction for the Grand Duchy of Baden and for Central Europe

A treaty between France and the Grand Duchy of Baden of 2 July 1857 launched an important German-French building project: the first railway-bridge over the Rhine River near Strasbourg. The foundation and the construction of the piers were taken on by the French East-Railway-Company together with the company Schneider et Cie. from Le Creusot, bringing in the new method of caisson foundation based on iron caisson-elements sunk into the river ground and put under pressure to enable the excavation by man. The superstructure, a box-girder in lattice-work from puddle-steel, was manufactured by the German company Benckiser Bros. from Pforzheim/Baden. They also applied

an innovative method of construction in moving the girders into position on rollers, nowadays known as incremental launching. Benckiser had tested this technique on railway-bridges in Switzerland several years before.

Hilal Tuğba Örmecioglu

Akdeniz University FFA, Department of Architecture, Antalya, Turkey
Bilge Küçükdoğan
Gazi University NIKER-TR Project Office, Ankara, Turkey
Aslı Er Akan

Republic of Turkey Ministry of Science, Industry and Technology, Ankara, Turkey
The Roots of Foreign Effects in Development of the Turkish Construction Sector [1719-1933]

Since the late Ottoman period, Turkish governments carried out technology transfer with self-determination and conscious initiative. This continual policy is not systematized but rather shaped randomly by the changing equilibrium in international affairs such as French-Ottoman affairs in the 1780s or German-Ottoman affairs in the 1900s. The construction sector was one of the most active areas in this transfer. In this study, the roots of this transfer will be explained in detail by focusing on the early periods of Turkish engineering since the establishment of technical education in the 18th century through its change with the financial politics in the 1930s. Specifically the period covered is that between 1719 and 1933, which are respectively the years of the ten-page report submitted to Sultan Ahmet entitled, “Establishment of a Foreign Engineer Troop under Bab-ı Ali Rule” by a foreign expert, De Rocheford, and the preparation of the first domestic government bonds for the construction of the Fevzipasa-Diyarbakir line.

Riichi Miyake

Fuji Women's University, Sapporo, Hokkaido, Japan,

Michiko Maejima

Keio University, Tokyo, Japan
A Study of Military Facility Planning from the Viewpoint of Technological Transfer from France to Japan

Now that the buildings of the former Army of Japan are facing the prospect of demolition, there is increasing demand that their historical importance be assessed and that ways be found to reuse or preserve them. Today, as examples of early Meiji barracks built in the mid-1870s, only four barracks still

exist in Aomori, Sendai, Nagoya and Shibata. The Army's architectural system has not yet been sufficiently studied. So far, the architectural prototype for Army buildings has not been found, but we can describe the architectural planning process and the prototypes both for garrisons, which were built on the site of ancient castles, and for barracks, which mixed the traditional Japanese carpentry and the positive introduction of new techniques from France. This paper intends to clarify the planning method for military garrisons and the early stages of the barracks' construction process by way of field surveys and archival documents.

Wednesday 3 July, 14:00-16:00 MALAQUAIS SITE, Lenoir 2

417. Organization of the Construction Site

Chair: **André Guillaume**, HTTP-CNAM, France

Lia Barelli

Sapienza Università di Roma, Italy

Construction Methods in Carolingian Rome [Eighth-Ninth Centuries]

In the city of Rome, the Carolingian period was marked by an exceptional volume of building activity due to the favourable political and economic conditions of the papacy. All the buildings of this period reveal the same construction characteristics: the attempt to imitate the techniques of classical antiquity is evident, but the norm in these structures, which differentiate them from the Roman ones, is the irregularity of the laying. The technical characteristics are only partly justified by the use of non-homogeneous materials as a result of their recovery or of hurried workmanship or even of a presumed loss of technical capacity. Among the principal causes one must also consider the possible employment of unskilled labour: some works are known to have been carried out through public tender and also using forced labour, made possible by the political and economic structure of the Papal State.

Andrea Bonavita

Università Iuav di Venezia, Italy

Building the New Prisons of Venice and Their Bridge [1591-1604]

Despite traditional construction techniques in the lagoon, the structure of the New Prisons of Venice, with their walls of massive Istrian stone and barrel vaults in masonry, remains really unique. In this paper several aspects of the building site are analyzed by means of the documentation held in the Archivio di Stato di Venezia: salaries and wages, the management of masons and the supplies of building materials. Particular attention is paid to the activity of stonemasons and the provision of Istrian stone, without forgetting to follow the operations for the erection of the "Bridge of Sighs."

Matthieu Pinon

GSA-ENSA Paris-Malaquais, France

The Building of the Arsenal of Le Havre in the 17th and 18th Centuries

This paper draws upon PhD thesis research currently underway, which is dedicated to the study of construction works that occurred within the Gravelle fortress close to the

port of Le Havre in the 17th and 18th centuries. More exactly, our objective is to understand the conversion of the castle's 13th century outbuildings into a cannon foundry, which began in 1627. Even if nothing remains of these buildings today, this study is possible thanks to rich archival sources, notably quantity surveys and other established prices from the repair of the building in the 17th and 18th centuries and a recently discovered archaeological survey conducted before its demolition in 1949. This constructive analysis, which we will call "an architect's reading of the archives," strives to understand how this modest-looking Norman building participates in the development of the perfect arsenal as embodied by Cherbourg in the 18th century..

Anne Conchon

Université Paris 1-IDHE, France

Katherine McDonought

Stanford University, CA, USA

Road Construction Sites in 18th Century France: Labor and Administration in Action

Historians remember that the French monarchy was able to construct a vast road network during the 18th century, while they forget a little too quickly how construction work in many places lingered on for decades, how some roads were never completed, and how others' alignments were subject to heated debate. The finished product represented an Enlightenment-era political initiative, a success story for the reforming royal ministers. The contrast between these politicized accounts of the road network and contemporary representations of the inefficiency of the *corvée* raises the following question: If the *corvée* presented such difficulties suggested by its detractors, how do we explain the results of this unprecedented public works project? Part of the response may be found in the study of the *corvée* – in its work practices on the road construction site. Our paper outlines technical specifications as well as the social dynamics and labor constraints of these road construction worksites.

425. Stone

Chair: **Jacques de Mandat-Grancey**, Fondation du Patrimoine, France

Dimitris Theodossopoulos

University of Edinburgh, UK

John Barber, Graeme Cavers, Andy Heald

AOC Archaeology Group, Loanhead, Midlothian, UK

The Achievement of Structural Stability in the Drystone Iron-Age Broch Towers in North Scotland

There is a growing need in archaeological literature to focus more on the fabric and direct insight derived from field monuments, in the case of brochs, going beyond typological analysis or speculations about the purpose of certain features. This study attempts to discuss the complexity of this type of Atlantic roundhouse in the construction and planning processes, combined with their structural design and performance, and also to treat brochs like architectural structures. Such focus can provide further valuable information on how stability was achieved in dry stone built structures of this scale. It can also augment what we learn about the technological culture and corresponding intellectual achievements of the period.

Turgut Saner, Kaan Sağ

ITU, Istanbul, Turkey

The Aeolian-Style Polygonal Masonry in Larisa [Buruncuk] and its Regional Context

Larisa [on the river of Hermos] is located in ancient Aeolis – western Asia Minor. Excavations held on the acropolis [1902, 1932-1934] by Swedish-German teams brought to light sixth century buildings of monumental character. They are constructed in polygonal work with masonry skills on andesite. The fort settlement in the east displays, as well, variations of polygonal masonry, dating back to the Archaic period. Traces of wedge-holes on single blocks reveal that they were taken from the quarries on the site. Polygonal works [foundations, retaining walls and independently rising wall sectors] are all done in double shells. Blocks are cut either in straight edges or in curvilinear form known as the “Lesbian Type.” They are placed mostly so as to build layers. The final surface treatment is generally made by a pointed or flat chisel. Similar techniques can be observed on other Archaic sites, such as Old Smyrna, Phocaea, Aegae, Assos and Neandreaia.

Wido J. Quist

TU Delft, Netherlands

Timo G. Nijland

TNO, Delft, Netherlands

A Mining Engineer in Heritage Land: A.L.W.E. Van der Veen and Early Research on Natural Stone for the Netherlands State Commission on Conservation [1920-1936]

Mining engineer A.L.W.E. van der Veen was the first scientist to become involved in material research on natural stone in monuments in the Netherlands. The paper provides a first brief overview of his life and activities in the field of natural stone research as a ground for interventions on monuments and discusses his legacy.

Angelo Bertolazzi

Department of Civil, Environmental and Architectural Engineering, University of Padua, Padua, Italy; GSA-ENSA Paris-Malaquais, France

Stone Cladding Techniques in French Modern Architecture [1920-1940]

The research studies the evolution of construction techniques in stone in France during the 20s and 30s related to new industrialized construction. It begins with the study of technical manuals and French journals [*La Construction Moderne, L'Architecture d'Aujourd'hui*]. This evolution begins from the French tradition of block masonry that has been improved upon in the 19th century. During the modernization and the industrialization of the 20s, it began to evolve to a mixed construction [stone and reinforced concrete], where modernity and tradition give rise to an unusual and experimental constructive solutions. In the 30s, instead, the stone cladding grows as a model of constructive rationality, where “modern” building techniques slowly converge toward new solutions. The modern cladding in stone of the 30s has a central role in France, where dialogue is possible, without contradiction, between modernity and tradition.

433. Vaults & Stereotomy 2

Chair: **Jacques Heyman**, University of Cambridge, UK

Rosa Senent Domínguez, Miguel Ángel Alonso Rodríguez, Enrique Rabasa Díaz

Polytechnic University of Madrid, Spain

José Calvo López

Polytechnic University of Cartagena, Spain

The Irregular Ribbed Vault of the Sacristy of the Cathedral of Saint-Jean Baptiste in Perpignan

The vault of the sacristy of the Cathedral of Saint-Jean Baptiste in Perpignan [France], constructed by the Majorcan architect Guillem Sagrera between 1433 and 1447, is an outstanding, yet strikingly unknown, example of rib vaulting. This paper analyzes the overall construction of the form of the vault, characterized by its highly irregular perimeter, with particular attention to an isolated decorated corbel that solves the problem of the wall support of a group of six ribs and is in stark contrast with the rest of the supports, which are completely unadorned. Given the extreme rigour of Sagrera in all his works [and this one in particular], this apparent “capriccio” must be justified not only by decorative or formal requirements, but also by the constructive logic of the Gothic vaulting system.

Rafael Martín Talaverano, Carmen Pérez De Los Ríos, Rosa Senent Domínguez

Polytechnic University of Madrid, Spain

Late German Gothic Methods of Vault Design and Their Relationships with Spanish Ribbed Vaults

The classification schemas of historical construction processes in Portugal are established in important ethnographic studies that have been undertaken since the end of the 19th century. In works by figures such as Leite de Vasconcelos [1858-1941] and Rocha Peixoto [1868-1909] we can find an extensive mapping of the relationship between material resources, social traditions and construction technology throughout the country. During the 20th century, this body of research was developed by other scholars such as Orlando Ribeiro [1911-1997], who applied the Human Geography methodology to establish the first clear distinction between the stone culture of the North, and the earth culture of the South, integrating them in a universal context. This paper shows the importance of these studies to the establishment of a comprehensive view of Construction History in Portugal and highlights research areas opened up by such seminal works.

Stefania Petralla

Faculty of Architecture, Polytechnic of Bari, Italy

Safavid Ribbed Vaults as a Masterpiece of Iranian Construction Techniques

Spanning with ribbed vaults is largely diffused in several countries. In Iran they represent a primary element in local architecture and have been realized with techniques never developed abroad. The maturation of this vernacular methodology is strictly connected with the materials, consisting in bricks and suffering for the shortage of timber. The first examples of these structures spread in Persia during the tenth century and reached new heights of achievement under the Safavids. The method for constructing these ribs was developed in several ways until this high-performing period when elaborated ribbed vaulting, made with complex patterns of intersecting brick arches were created, as a structural and a decorative device. From this moment on, a big variety of spaces is covered using this system. This shows the ability of brick-workers who articulated several formal potentialities for addressing a structural problem, turning a weakness into a masterpiece.

Giuseppe Fallacara

Facoltà di Architettura, Dipartimento ICAR, Politecnico di Bari, Italy

The Lecce Vault: History, Construction Techniques and New Design Perspectives

In the region of Puglia in southern Italy, from the late 16th century onward and continuing to today, one finds the tradition of a particular type of composite vault called the Lecce Vault [*volta leccesse*]. This vault is found in the geographical region of Salento and particularly in the cities of Lecce and Brindisi. Historically this zone was called the Terra d’Otranto. The Lecce vault, which derives its name from the eponymous city, is also designated as a “star vault,” because, when viewed from below its form resembles a star. As a composite vault, the Lecce Vault combines features of all the canonical vaults: barrel vault [semi-cylindrical], sail vault [portion of a sphere], groin vault [composed of the intersection of two barrel vaults whose wedge-shaped parts are called in Italian *unghie*], and cloister vault [composed of sections of a cylinder called in Italian *fusi*].

444. Infrastructure & Public Works, Bridges

Chair: Teruhiko Yoda, Waseda University, Japan

Ivan Ferrari

University of Salento, Lecce, Italy

The Roman Bridges of the Via Traiana: An Innovative Building System

A study on the bridges of the Via Traiana, built in the second century A.D. between Benevento and Brindisi in the south of Italy, carried out through an accurate bibliographic research, surveys and technical drawings of the still visible ruins, has enabled the realization of 3D models, highlighting the different phases of the construction and reproducing the archaeological landscape. The new elements deriving from this study increase the knowledge of the construction solutions adopted during the Roman Imperial Age.

Stefan M. Holzer

Universität der Bundeswehr München, Neubiberg, Germany

Innovation in 19th Century Vaulted Bridge Construction

In the historical perspective, the development of masonry arch bridges in the 19th century is somewhat eclipsed by the rise of iron bridge construction. However, the present contribution shows that the processes of masonry arch bridge construction underwent a radical and unprecedented change during the 19th century, and that early concrete bridges were unthinkable without this development. The change involved the usage of completely new lifting gear and cranes, a switch in the paradigms of falsework design, the employment of cement mortars, enabling the construction of wide-span arches with "small materials," and the invention of new construction principles such as arch construction by rings or by sections with later keying, and, finally, three-hinged arches. All these changes were not independent of each other, and all of them owed a lot to the developing science of construction. The present contribution gives a general outline of the development and shows the relation between the individual aspects.

Dario A. Gasparini

Case Western Reserve University, Cleveland, OH, USA

Sunderland, Birdsall and the Roebling Co: Development and Diffusion of Construction Technologies for Suspension Bridges, 1928-1952

The paper describes innovations by the John A. Roebling's Sons Company in the design and construction of suspension

bridges in the period from the late 1920s to the early 1950s. Specifically the contributions of Charles Sunderland and Blair Birdsall are discussed. Sunderland devised an efficient method for the assembly of in-situ spun main cables that was adopted worldwide. The pre-stretching technology pioneered by Roebling enabled the assembly of main cables using pre-stretched, pre-socketed strands. Roebling engineers designed innovative anchorages, saddles, and decks for pre-manufactured small suspension bridges for erection in remote locations. In response to the failure at Tacoma Narrows, Sunderland developed a cable truss suspension bridge stiffened by prestressing.

Eberhard Pelke

Hessen Mobil – Roads & Traffic Management, Wiesbaden, Germany

Karl-Eugen Kurrer

Ernst & Sohn, Berlin, Germany

The Development of Multi-Cable-Stayed Bridges

The work of Hellmut Homberg embraces all the materials and structural forms of modern bridge-building. It is even broader than he himself realized, even though his great passion was major bridges. Homberg reached the pinnacle of his art of bridge-building between 1962 and 1967. Within a short space of time he developed, patented and built the two fundamental types of multi-cable-stayed bridge. And his last main patent [1967] points the way forward for multiple-span multi-cable-stayed bridges; the Rhine crossing at Neuwied–Weisenthurm became the prototype for the Millau Viaduct. It remains a tragedy that Homberg's pioneering designs and studies for stringing together multi-cable-stayed bridges were not pursued during his lifetime. This trilogy is a first attempt to document Homberg's work, publications and relevant literature. This is the first systematic appraisal of his contribution to the development of the multi-cable-stayed bridge. It includes previously unpublished designs and concludes with a *Catalogue Raisonné* of his multi-cable-stayed bridges.

306. Rules & Standards, Building Regulation Compared

Chair: Musa Sroor, Birzeit University, Palestine

Julien Puget

CNRS UMR 6570 TELEMME – MMSH, Aix-en-Provence, France

Construction Market Organization in the 17th Century: Norms, Actors and Practices - Examples of Extension Plans in Aix and Marseille

In the absence of institutions specifically responsible for supervising construction, it is difficult to know the rules and practices relating to the construction of private buildings on a day-to-day basis. Extension plans for the cities of Aix-en-Provence and Marseilles in the mid-17th century offer an opportunity to compare administrative sources and contracts and to identify three phases in the authorization of house-building under the Old Regime. The two first phases correspond to the development of the project and its installation on the land, including numerous surveys and alignments of land and buildings. The final phase relates to inspections to verify that builders respected the terms of their permits for construction and new regulations on public law and order that were being issued. This study contributes to the social history of construction and focuses attention on the various actors in this market.

María Teresa Paliza Monduate

University of Salamanca, Salamanca, Spain

Limitations Stemming from the Legal Regulation of Designs of Foreign Architects in Spain in the 19th Century: The Case of the Basque Country

During the second half of the 19th century, many Spanish towns had building regulations and, to obtain a building permit, the project had to be signed by architects recognized by the San Fernando Academy of Fine Arts in Madrid. In practice, this measure impeded foreign architects from presenting projects for buildings in Spain. Nonetheless, certain developers wishing to construct buildings with structural and architectural characteristics not in line with the dominant trends in Spain chose to use as front men local architects willing to sign plans designed by foreign architects in order to fulfill the legal requirements. We present a review of cases in the Basque Country and their consequences on the construction processes of the buildings involved.

Robert Carvais

CNRS-Université Panthéon-Assas, Paris / ENSA Versailles, France

For a Comparative Study of Construction Laws

How can one understand construction law in a historical and comparative perspective? According to one theory, which is the case in French law, the meaning of the words allows us to distinguish three possible combinations between law and construction. The word "construction" encompasses not only the action of building, but also the result of this action, that is to say the built object. Thus, there exists a law concerning the act of constructing as well as a law concerning the constructed object. However, we would not be comprehensive in our thinking if we did not also consider construction law as its own discipline. What's more, an understanding of these three ways of understanding construction law could become enriched by considering how other cultures deal with such laws. Without being able to cover everything, this paper attempts to identify some of the invariants and outline some of the specificities of construction regulations in different countries. This approach seeks to invite foreign lawyers and historians to come out in favor of a common research program in comparative construction law, which would lead to the creation of a European or even international network concerned with the regulation of construction culture.

Keynote Lecture

Wednesday 4 July, 18:30-19:30 CNAM SITE, AMPHI PAUL PAINLEVÉ

Shigeru Ban

Architect, Tokyo, Japan

Works and Humanitarian Activities

Shigeru Ban, born in Tokyo in 1957, is an architect, designer and set designer. After attending the Southern California Institute of Architecture and Cooper Union School of Architecture, he founded his firm in 1985. Ban is considered one of the most innovative architects of his generation and is, in particular, known for his development of paper as a construction material.

Among his best known projects, there are notably: the Curtain Wall House in Tokyo [1995], the Japanese Pavilion for the Hannover World Exhibition in collaboration with Frei Otto [2000], the Nicolas G. Kayek Center in Tokyo [2007] and the Centre Pompidou in Metz [2009]. He is also

known for his commitment to humanitarian causes and, in particular, to disaster relief initiatives. Among his works in this domain, we find: the Paper Log House and Paper Church built after the Kobe Earthquake [1995], Paper Emergency Shelters for the Byumba Refugee Camp in Rwanda [1999], Emergency Shelters built after the Gujarat Earthquake in India [2001], the reconstruction of the fishing village of Kiranda after the Sri Lankan Tsunami [2004] and a temporary school in Chengdu, China after the Sichuan Earthquake [2008]. In 2011 he was awarded the Auguste Perret Prize in recognition for his mastery of integrating technical knowledge into innovative architectural design.

Sessions

Thursday 5 July, 9:00-11:00 LA VILLETTE SITE

410. Structural Analysis & Modeling 1

414. Technical Literature, Images & Representation

418. Scaffolding and Machines

426. Reuse & Recycling

427. Earthen & Plaster Structures

434. Shells & Thin Vaults

442. Natural & Technical Risk, Earthquake Design

445. Infrastructure & Public Works, Transportation

410. Structural Analysis & Modeling 1

Chair: Patricia Radelet-De Grave, Université catholique de Louvain, Belgium

David Wendland

TU Dresden, Germany

Arches and Spirals: The Geometrical Concept of the Curvilinear Rib Vault in the Albrechtsburg at Meissen and Some Considerations on the Construction of Late-Gothic Vaults with Double-Curved Ribs

An analysis of the geometric design of a late Gothic vault with curvilinear ribs is carried out interpreting the 3D measurement data, formulating hypotheses on the design directly from the built artifact, with a working method not common in surveying until now. It is demonstrated how the geometric definition of the arches in the vault can be characterized. The general methodological problems regarding the interpretation of the geometric features of surveyed buildings and the interpretation of design processes in architecture are discussed. Further, the necessity of revising the current state of knowledge on Gothic vault design is underlined. Some final remarks discuss the design and construction of the masonry shell in vaults of this kind.

Thierry Ciblac

ENS Architecture Paris La Villette / MAP-MAACC CNRS UMR 3495, France

Analysis of Philippe de la Hire's Arch Theory Using Graphic Statics

In Proposition CXXV of his 1695 *Traité de mécanique*, Philippe de la Hire gives a graphic method for studying arch equilibrium that is considered the first scientific approach to this subject. With some restrictive hypotheses such as frictionless contact and radial joints, he gives a particularly simple geometric construction by which to determine the weight of the stones. This paper analyses this method using graphic statics – another graphic method, formalized by Culmann in 1864 – in order to point up the reasons for its simplicity and the role of each hypothesis. The first part deals with the relationship between some of the other propositions in de la Hire's *Traité* and the graphic statics method. An equivalent duality between force polygon and funicular polygon is then brought out. In the second part, the proposition on arch theory is analysed using graphic statics. A generalization of the method, which was touched upon but not illustrated by de la Hire, is proposed.

Javier Suárez, Laura Cirera

School of Architecture, University of Granada, Spain

Structural and Constructive Analysis of the Acequia Real Aqueduct in the Alhambra, Granada

This work presents a documental study of the historic beginnings, the constructive description and the analysis of the mechanical behaviour of the Acequia Real Aqueduct in the Alhambra of Granada. This historic structure is the keystone of the Nasrid Palace's hydraulic system. Construction of the Acequia Real was commissioned by King Muhammad I in 1238, when he decided to build the new palatial city of the Alhambra. The entry of the Acequia Real into the citadel of the Alhambra is found by passing through an aqueduct dating back to the beginning of the 18th century, built with ashlar, on a semi-circular arch eight m. in diameter and 11m. in height. The work shows: the geometric modelling of the aqueduct, the study of the stone material, through investigation of its origin, petrographic analysis and stereotomy; the pathologic inspection of the building and the modelling of its mechanical behaviour through application of the Fundamental Theorems of Limit Analysis, according to J. Heyman and S. Huerta, including detailed graphical diagrams on the position of the thrust line. Finally, we will draw conclusions on its stability and security level.

Santiago Huerta

Universidad Politécnica de Madrid, Spain

Structural Analysis of Thin Tile Vaults and Domes: The Inner Oval Dome of the Basílica de la Virgen de los Desamparados in Valencia

The inner oval dome of the Basílica de la Virgen los Desamparados, built in 1701, is one of the most slender masonry vaults ever built. It is a tile dome with a total thickness of 80 mm and a main span of 18.50 m. It was built without centering with great ingenuity and economy of means, thirty-three years after the termination of the building in 1667. The dome is in contact with the external dome only in the inferior part with the projecting ribs of the intrados, the lunettes of the windows and, in the upper part, through 126 inclined iron bars. This unique construction was revealed in the 1990s in the studies previous to the restoration of the Basílica and has given rise to different theories about the mode of construction and the structural behaviour and safety

of the dome. The present contribution aims to provide a plausible hypothesis about the mode of construction and to explain the safety of the inner dome that has stood, without need of repairs or reinforcement, for 300 years.

414. Technical Literature, Images & Representation

Chair: **Chen Zhao**, Nanjing University, China,

Maria Grazia D'Amelio

Università Tor Vergata, Rome, Italy

Fabrizio De Cesaris

Università La Sapienza, Rome, Italy

Moving St. Peter's Obelisk as Seen in the Engravings of Giovanni Guerra and Natale Bonifacio: A Transmission of Knowledge, or Pure Propaganda?

The process of moving St. Peter's obelisk [1586] was immortalized in two famous engravings by Giovanni Guerra and Natale Bonifacio, which were produced at that time. Four years later the creator of this memorable enterprise, Domenico Fontana, published *Della Trasportazione dell'Obelisco Vaticano* [1590], which describes how the monolith was removed from the original location, transported and then erected in St. Peter's Square. Historiography has always considered this volume as a means for spreading highly specialized technical knowledge, a reference when undertaking similar enterprises. The illustrations were certainly much admired, though they attracted less technical interest. In fact, they still had to be proved in the context of the debate between mechanical theory and practice, which was as yet in an embryonic stage. Moreover, one wonders if the images contained sufficient information to pass on the very specialized "science" of moving large monoliths. This paper aims to analyse the technical scope of the illustrations, and their effectiveness as spreaders of knowledge.

Jean-Sébastien Cluzel

Institut national d'histoire de l'art, Paris, France

Hokusai Manga as a Reference Construction Book

Two of the illustration books of the master painter Hokusai Katsushika [1760-1849] are dedicated to architecture: The fifth book of *Hokusai Manga* [1816], and *New Models Illustrated for Craftsmen* [1836]. Therefore it appears a little strange that those two albums are still not considered as a "valuable pieces" among construction books of the Edo period [1603-1868]. Proceeding from a short structural analysis of a representative variety of 17th, 18th and 19th century Japanese publications related to construction, this paper will explain some relation between construction books and Hokusai's albums, showing the necessity of including them in the bibliography of construction books. This conclusion allow the author to discuss the limits of the field

of construction history in Japan, and to question the "non existence" of architects in pre-Meiji Japan. By this paper, the author hopes to shed light on Hokusai's work as well as contribute to the elaboration of a transnational construction history.

Javier Girón

Universidad Politécnica de Madrid, Spain

A Review of the Depiction of Ancient Construction by Charles Chipiez in L'Histoire De l'Art

This paper critically reviews the analytical drawing of construction in the prominent Georges Perrot's and Charles Chipiez's *Histoire de l'Art dans l'Antiquité*, which has not yet been thoroughly studied. The chapters devoted to architecture, for which Chipiez was responsible, cover from Egypt [1882] to Greece [1898]. Chipiez, with a rationalist approach, analyzed and recreated ancient design using perspective and axonometric projections to represent construction details that in earlier literature were drawn in planar projections. This approach can be compared to that of Choisy in his *Histoire de l'Architecture* [1899]. A comparison between both works has enabled us to understand the value of Chipiez's contribution to architectural literature and drawing. It seems Chipiez's work anticipated some of Choisy's drawings and subjects he discussed in his first chapters [Egypt and Assyria]. The influence of authorities such as Hittorff is evident in both Chipiez's and Choisy's studies of Greek architecture, especially in the depiction of the construction processes.

Hilary Bryon

School of Architecture+Design, Virginia Tech, VA, USA

Construing Construction with Drawings: Robert Willis' and Auguste Choisy's Axonometric Representations of Vaulted Structures

English engineer Robert Willis extended his mechanical-analytical approach and graphic methods to architecture and archeology in the early 19th century. His unprecedented graphic demonstrations used isometric projection to clearly convey his construing on construction. Willis constructed his graphic thoughts in two different ways, in Remarks on the Architecture of the Middle Ages [1835], the drawings articulate an abstraction of arcuated building components that form the whole and in "On the Construction of the

Vaults of the Middle Ages," [1842] the representations appear as less analytical while making manifest a mechanical relationship between the stones, as component parts, and their assembly, as vaulted structures. This paper examines the methods employed by Willis to reveal and embody vaulted construction, but also how Willis' rational, analytic practices and graphic axonometric constructions influenced those by French engineer Auguste Choisy in his *L'art de bâtir chez les Romains* [1873] and *L'Histoire de l'architecture* [1899].

418. Scaffolding and Machines

Chair: **Ledlie Klosky**, United States Military Academy, West Point, USA

Lorena Fernández Correás

University of Valencia, Spain

The Study of Medieval Lifting Machines Thanks to Iconography: An Example in Mediterranean Machinery

The paper presents a study of medieval lifting machines on construction, based on the use of iconography as the primary and main source of research. Traditionally, the discipline has been used as a visual support in other subjects, but in my research the iconography is used as a primary resource because it provides a wealth of information per se. The analysis of it joins the multidisciplinary work of comparing the results with disciplines such as architecture, physics or engineering research proving unique in its field and so far the only jobs that have seen the iconography have done so from a standpoint of repertoire, without further visual importance.

Inge Bertels

Vrije Universiteit Brussel / FWO & Universiteit Antwerpen, Brussels/Antwerp, Belgium

Scaffoldings: 19th Century Discourses on Innovative Scaffolding Techniques within Architecture and Construction Journals

This paper focuses on innovative scaffolding techniques within the second half of the 19th century and is based on a profound study of a selection of contemporary architectural and construction journals [discourse and iconographic presentation and promotion]. The image these journals clearly puts forward is that contractors and trades evolved toward a strong focus on the discovery of new machinery and tools capable of performing the maximum of work and safety, with the minimum of trouble and expenses. As such these journals offer a first glimpse of what innovators of scaffolding techniques and construction tools were seeking. Based on this analysis, this paper brings a first ‘typology’ and ‘evolution’ of innovative scaffolding techniques, suggests further methodological procedures and questions how various actors tried to ameliorate the mechanization and rationalization of the building processes on site.

Richard C. Ryan

University of Oklahoma, Norman, OK, USA

Development and Use of Mechanized Heavy Construction Equipment in the United States

Since the mid 1700s, U.S. construction history can be divided into four basic earthmoving, excavating and hoisting equipment development time spans or eras: canals, railroads, highways and high rises. Fundamental mechanical and operating principles for earthmoving, excavating and lifting equipment were proven and documented well before 1800. The challenge of the 19th century was to mechanize crude human, horse, mule or ox-drawn construction. The invention of the steam engine as a power source started the rapid evolution of heavy construction equipment design, manufacture and use and began the change from tools to machines. Discussion focuses on the evolution of earthmoving, excavating and hoisting machines from barges to rails to wheels and tracks. A timeline highlighting the construction eras is intended to show the relationship of equipment developed for construction of United States infrastructure and building projects, significant events or inventions and the equipment needs of the different types of work.

Nicoletta Marconi

University of Rome Tor Vergata, Italy

Innovation and Tradition in the Reconstruction of the Basilica of St. Paul Outside the Walls in Rome [1825-1928]: Technologies, Procedures, Protagonists

The decision to rebuild the ancient Basilica of St. Paul Outside the Walls, destroyed by a fire in 1823, was taken immediately. The work began in 1825 and continued for 100 years. There have been many studies tracing the project and the stages of the reconstruction from the 19th century on. Less frequent have been the contributions supplied by the methods used to raise the multitude of columns that were placed at regular intervals around the interior of the Basilica and the monumental four-sided portico. This paper focuses on this last aspect, illustrating the technical contributions offered to the San Paolo work yard by the Fabbrica di San Pietro in the Vatican, the papal institution responsible for overseeing the worksite of the new Vatican Basilica from the 16th century, whose role was crucial in the execution of the technically delicate and complex operations in the reconstruction of St Paul’s.

426. Reuse & Recycling

Chair: **Joël Sakarovitch**, GSA-ENSA Paris-Malaquais, France [TBC]

Stéphane Büttner

Centre d'études médiévales d'Auxerre, CNRS / Université de Bourgogne, Auxerre, France

The Use of the “Already There”: Reuse and Recycling for Monumental Building in the West in Late Antiquity and the Medieval Period

Historians of building have always wondered about the practice of reuse, focusing mainly on obvious cases, such as the reuse of Gallo-Roman carved blocks to build city walls at the end of Antiquity. The sometimes ostentatious character of certain reuses has been interpreted as a manifestation of the desire to anchor some symbolic buildings in a long history. Nevertheless, the discreet recycling of materials has undoubtedly occurred in a far higher proportion of buildings. It is necessary to evaluate this proportion in order to take it into account in reflections on the technical and economic organisation of construction during Late Antiquity and the Medieval Period. The issue of reusing materials [stone and architectural terracotta] and even entire walls, as new architectural components [mortars, components for foundations and elevations, or roofing], opens up a whole field of reflection on the functioning of construction but also deconstruction, as the two operations sometimes appear nested.

Emanuela Montelli

Università degli Studi “Roma Tre”, Italy

The Reuse of Granite Columns in Rome, 15th-16th Centuries

Between the second half of the 15th and the early decades of the 16th centuries, Roman architecture was characterized by the presence of reused columns in various different types of marble [*bigio antico*, breccias, *cipollino*, granite, travertine], reworked in accordance with their new function in contrast to what occurred during the Middle Ages. Initially, column shafts were reused without any distinction between the types of materials available; later, especially after the construction of Palazzo della Cancelleria, monolithic granite columns [grey and red] were sought out and these took on a primary role compared to other materials. Only in the works of Bramante is the reworking of the granite columns, already problematic due to the hardness of the stone, further complicated by the execution of the entasis. The preference for granite can be explained by both technical reasons and the

desire to make reference to Antiquity; this material made it possible to create shafts of the desired size, much appreciated during the Imperial period, without running the risk of breaking the stone.

Martin Bachmann

German Archaeological Institute, Istanbul, Turkey

The Revival of Classical Building Techniques in Late Ottoman Architecture in Bergama, Turkey

This article discusses the buildings of the Greek middle class in Bergama, Turkey, dating from the second half of the 19th century. To understand what this style of building represents, an awareness of the social and historical background behind its emergence is of great importance. In addition to questions of typology and design, we must also pay special attention to aspects of construction technology, which to date has hardly been studied at all. It turns out that ancient architecture and building practice served as a model. The adoption of construction techniques was accompanied by large-scale recycling of building materials from ancient ruins. The townhouses and civic buildings of the Greek population of Bergama were erected upon the intellectual and material substratum of ancient Pergamon. They bear witness to a keen interest in the legacy of antiquity, which was most likely deepened by the German excavations beginning in 1870. Alongside the revival of classical building techniques, surprising innovations are also to be encountered, such as stone-iron bracing methods and adhesives that betray a boldly experimental approach within the building industry of the period.

Sachiko Okada, Ichiro Kobayashi

Department of Civil and Environmental Engineering, Graduate School of Science and Technology, Kumamoto University, Kumamoto City, Japan

Koichi Nakama

Department of Civil Engineering, Graduate School of Technology, Kyushu Institute of Technology, Kitakyushu City, Japan

A Study on Distribution and Reuse of Tram Line Paving Stones in Japan

Trams used to be seen in most major cities in Japan between early 1900 and the 1950s. Stone slabs were generally used for the track paving at the time. Since then, quite a few tramlines have fallen into disuse, and their slabs have been

re-used elsewhere in the country. This paper clarifies the following three points on the distribution and use of the slabs. 1) Flagstones were a standard distribution product subject to reuse [domestically produced granite]; 2) New quarries were developed in response to increasing demand for the flagstones; 3) As there was a large quantity of disused flagstones, they were sold and reused. According to one case of use diversion, the texture of the old flagstones was popular as it was reminiscent of cities in bygone days.

Thursday 5 July, 9:00-11:00 LA VILLETTE SITE, Amphi 7

427. Earthen & Plaster Structures

Chair: **Dimitris Theodossopoulos**, University of Edinburgh, UK

Annick Daneels

Universidad Nacional Autónoma de México, Mexico City, Mexico

Luis Fernando Guerrero-Baca

Universidad Autónoma Metropolitana Xochimilco, Mexico City, Mexico

Earthen Building Techniques in the Humid Tropics: The Archaeological Site of La Joya, Veracruz, México

The pre-Columbian site of La Joya, on the Mexican Gulf coast, is extremely valuable due to its size, antiquity and historical relationships, but above all, its building materials, because it was entirely built using raw earth, though located in an admittedly adverse environment for this type of building. However, ancient settlers developed strategies that made it possible for the city to remain standing through the first millennium A.D. During the 20th century, the site has suffered a dramatic process of destruction by brick manufacturers. This situation gave rise to an archaeological project that has produced hitherto unknown data about the construction of earthen living spaces that are remarkably adapted to their natural environment. The findings are important because there are no similar studies in this region; they provide knowledge about the effective use of raw earth that could support the design of new buildings to meet growing demands for housing.

Anna Antonini

Politecnico di Milano, Italy

Persistence of the Perishable; Wattle-and-Daub Architectures in the Roman Period: A Census of the Archaeological Findings in Gallia Cisalpina and the Case of Mediolanum

This paper aims to provide a tool for a systematic study of perishable material building techniques in Northern Italy. The research considers findings from published excavations. This work identifies five different building techniques, where perishable materials are employed. The results are presented in synoptic tables relating the type of findings, place of discovery, archaeological context and chronology. This census is the first step in the analysis and understanding of construction methods of perishable material buildings. In the second part of the paper, a brief synthesis of the case of Mediolanum is presented: this work identifies five different building techniques, where perishable materials are employed.

Fernando Vegas, Camilla Mileto, Maria Diodato, José García Soriano, Carles Grau Giménez

Universidad Politècnica de València, Spain

Traditional Structures Made with Gypsum Pillars: A Reasoned Hypothesis

Gypsum is nowadays considered an auxiliary material and therefore only employed in internal plastering, mouldings and artistic decoration. Nevertheless, before the diffusion of reinforced concrete, gypsum even had a structural role in traditional construction in some regions in Spain. In fact, in some areas, gypsum was always employed as the only mortar for structural pillars, as poured material for jack vaulting floors, as internal plastering and external rendering, as mortar to bond thin stone slabs in partition walls, as reinforcement for rammed earth walls, etc. Especially, pillars made of gypsum and stones are a token of its performance in dwellings up to four stories high. The research presented here is based upon a detailed constructional study made on 96 gypsum pillars in Rincón de Ademuz [Valencia]. All these data have made it possible to understand a building element often ignored due to a lack of knowledge about its structural performance and durability.

Luca Boiardi, Maria Regina Tedeschini,

Riccardo Gulli

Bologna University, Italy

History and Technique of an Italian Wooden Floor System Based on Reeds and Gypsum Plaster Frame: The Case of Reggio Emilia

The paper deals with a wooden floor system based on the traditional double frame floor, where a continuous layer made of reeds and gypsum named *arellato* replaces planking, similar to *camorcanne* and *incannucciato*. Differently to these techniques, *arellato* was employed as a slab in wooden floors and could be considered characteristic of Reggio Emilia's specific building type. Its diffusion during the 18th century as a floor frame is related to the availability of raw material, placed at a short distance from the construction site, and its success during the 19th century is related to thermal, acoustic and fire resistance performances as main factors for its achievement in relation to the research of comfort and safety. However the main innovation is to use mats as slabs or, in other words, to assign them a role both as a load-bearing frame and as a horizontal flat surface for the floor finishing.

434. Shells & Thin Vaults

Chair: John Ochsendorf, MIT, USA

Ciarán Conlon

University College Dublin, Ireland

James Hardress de Warenne Waller and His Contribution to Shell Roof Construction, Concrete and Fabric Formwork Technologies

Born in 1884, engineer James Hardress de Warenne Waller was an expert in the production of early reinforced concrete and concrete shell construction. During World War II, he developed an innovative method of building concrete shell roofs with a catenary arch cross-section in pure compression; this eliminated the need for steel reinforcement. Instead of conventional formwork, he used fabric supported by reusable falsework. The system was revolutionary in both its economy of materials and structural principles. Waller's advancement of concrete shell construction remains under-recognized despite it being broadly influential on 20th century architects and engineers, most notably Felix Candela who adopted Waller's system of construction in the first of his numerous works and continued the use of similar double curvature structural principles into his latter works. This current research documents Waller's principal contributions to concrete technology and examines the extent of influence his innovative work had.

Pepa Cassinello

Polytechnic University of Madrid, Spain

Pioneer Concrete Shells in Spanish Architecture: The Innovation System-Design of Ildefonso Sánchez del Río

The legacy of Ildefonso Sánchez del Río Pisón [1898-1980] contains some of the most pioneering Spanish concrete shells. It's a fact that "Modern Architecture's Thin Shells Adventure" had just begun when he designed and built his first work in Spain [1924]. In the international context prevailing in the 20s, reinforced concrete was still evolving. The first thin concrete shells were built by Dyckerhoff and Widman in Jena, Germany [1922-1925]. Ildefonso Sánchez was looking for a system to design concrete shells in a simple way. Finally, he founded his own and innovate system based on a similar method to the ribbed Gothic Vault. He used his system to build a very different kind of ribbed concrete shell, such as the Sport Hall of Oviedo, Spain [90 m. span]. This paper aims to discuss the innovations of his system design in the international context.

Roland May

BTU Cottbus, Germany

Shell Wars: Franz Dischinger and Ulrich Finsterwalder

In the winter of 1923, just after having finished university, Ulrich Finsterwalder entered the building enterprise Dyckerhoff & Widmann, which recently had developed a groundbreaking method for the construction of thin concrete shells. Within the company he soon established himself as the second driving force besides another mastermind: Franz Dischinger. In less than a decade, both engineers would provide the theoretical and practical basis that enabled thin concrete shell constructions to conquer the whole world. The article takes a closer look at their complicated collaboration. As a result, it aims to raise questions about originality and authorship in engineering – questions that normally are ignored in a research field whose objects of investigation usually arise from collaborative endeavors.

Maris Suits

Estonian Academy of Arts, Tallinn, Estonia

Reinforced Concrete Shells in Estonia during the Soviet Period: Science and Practice

This paper presents a discussion of the Estonian school of concrete shell research, led by Professor Heinrich Laul. The school was characterised by a strong experimental emphasis and a drive to practical application. New calculation methods were developed [e.g. the shear stress approximation method], which allowed engineers to determine [with relative ease] the forces present in a reinforced concrete shell. Experimentation on scale models was widely used in research. Paradoxically, although this scientific research was aimed at finding practical methods for engineers, only a few reinforced concrete shells were constructed in Estonia. The paper introduces the built shell structures and discusses the reasons why shells were inappropriate in Soviet Estonia.

442. Natural & Technical Risk, Earthquake Design

Chair: TBA

Hélène Dessales

École normale supérieure, AOROC, UMR 8546, Paris, France

Not Built in a Day: Awareness of Vulnerability and Construction Techniques in Roman Times

This paper tackles two issues that have never really been raised before in the history of Roman construction. Firstly, we shall try to interpret the factors of architectural vulnerability as they are set out in a selection of different texts: literary narratives, inscriptions, juridical sources. Two major categories can be identified, the first is human, featuring construction mistakes that lead to architectonic defects; the second is natural, covering a variety of manifestations ranging from erosion to violent episodes such as earthquakes. Secondly, we investigate the reasoning adduced in the choice of construction techniques, which sought to avoid instances of fragility and ensure stability and durability or *firmitas* and *perpetuitas*.

Giovanni Fatta, Tiziana Campisi, Calogero Vinci

Dipartimento di Architettura, Università degli Studi di Palermo, Italy

Tiled Vaults in Western Sicily: Originality and Continuity of an Imported Building Technique

The search for alternatives to wood for floorings has led to very interesting experiments on vaulted structures, with diffusion in specific areas. We analyze the Sicilian ones consisting of three layers of tiles with plaster, introduced in the mid-18th century, reinterpreted with local materials and building culture, with original and ingenious solutions as to the seismicity of area. The oldest examples in Palermo date back to the period following the earthquake of 1726, considered a good solution because of their lightness and presumed monolithic structure, able to reduce the pressure on walls. This paper is an assessment of this building system, that we found during many restoration works. Totally ignored by official current technical culture, tiled vaults usually are demolished or transformed into decorative ceilings. A comparative examination of several cases has enabled us to properly assess the actual possibility for maintenance, rehabilitation or re-proposal, whilst preserving the structural function.

João Caldas, Rita Lisboa

Instituto Superior Técnico–Universidade Técnica de Lisboa, Portugal

The Use of Vaults in the Reconstruction of Pombaline Downtown Lisbon

Usually, the system of construction used in the rebuilding of downtown Lisbon after the Great Earthquake of 1755 is described as having vaulted ground floors. Some writers mention three types of structures used to support the first floor: vaults, wooden beams on stone arches and wooden beams supported just by pillars and/or walls. However, we still did not know whether the three types coexisted from the start of the reconstruction, or whether they resulted from the vicissitudes of construction methods over time. After our research, we may conclude that the three constructional solutions coexisted from the outset. Moreover, differently from what was once presumed, the vault was the least used constructional system to cover the ground floor and support the first floor of rentable buildings in Pombaline downtown Lisbon.

Akio Sassa

RFR Engineers, Paris, France

The First Earthquake-Resistant Structures in Japan: Forgotten Lessons from the Earthquake of Ischia [1883], Nobi [1891] and San Francisco [1906]

Scientific studies on earthquakes and earthquake resistance started in Japan in the 1870s. They were led by Western scientists and engineers hired by the government. The earthquake of Ischia [1883, Italy] influenced the Japanese a lot; the Ischia building code became a reference although it was lacking scientific basis. After the earthquake of Nobi [1891], the Japanese started developing new reinforcing methods based on their observations. Most of them were empirical, but some prototypes designed by the seismologist F. Omori were based on his static seismic calculation. In 1906, he visited San Francisco with the architect T. Sano to observe earthquake-damaged buildings. Sano deepened their analysis for a decade to publish a theory-based manual of earthquake-resistant structures. Thanks to this, the Japanese were able to analyze correctly the damages caused by the Kanto earthquake [1923] and further develop earthquake-proof structures.

445. Infrastructure & Public Works, Transportation

Chair: Naoto Tanaka, Kumamoto University, Japan

Matteo Porrino

ENSA Strasbourg/GSA ENSA Paris-Malaquais, Paris, France

Notes on Technological and Architectural Aspects of London Transport Power Stations and Substations, 1880-1915

Through the analysis of several London buildings, this text aims to highlight transformations in architecture and construction associated with the electrification of public transport and the creation of the London Underground at the end of the 19th century. Power plants, the shape of which crystallised in the form of juxtaposed twin halls, can be considered magnificent building exceptions – for their unprecedented steel frame, for example. They are also interesting as a starting point to reflect upon the functional limits of major installations on the edge of cities. During the same period, electrical substations were an exercise in reinterpretation and adaptation of industrial buildings to the existing urban surroundings both in terms of language, which goes from historicist eclecticism to architectural rationalism, and in terms of construction modalities, especially regarding the implementation of technologies aiming to reduce nuisances or the management of the life cycle of productive units.

Ted Shelton

University of Tennessee, Knoxville, TN, USA

The Highway Comes to the American City: Automobility, Urbanity and the Functioning of City Streets

Near universal individual automobility, when extrapolated to the scale of a city, overwhelms existing street networks and spurs the creation of dedicated urban highways. The search for workable urban highway typologies in the United States throughout the 20th century was burdened by a focus on the functioning of the system as a whole, romantic notions of the rural highway and utopian ideals that largely discounted the functioning of the traditional city street. Accordingly, the resulting construction had profound and largely negative implications for the American city. This paper examines the pressures that led to the construction of American urban highway and chronicles the development of early and midcentury American urban highway typologies as well as strategies used in their construction.

Evangelia Chatzikonstantinou, Paschalis Samarinis

National Technical University, Athens, Greece

Areti Sakellaridou

Rheinisch-Westfaelische Technische Hochschule, Aachen, Germany

Road Construction in Greece during the Interbellum: The Makris Project

The paper discusses aspects of road construction in Greece during the Interbellum and it analyses the inscribed social and spatial ideas within road infrastructure planning and construction. It focuses on the most important national road scheme of that period, known as the Makris Project and it aims at contributing to the transnational discussion on mobility infrastructure construction through a site specific, spatial and sociotechnical approach. Geographical, economic and cultural asymmetries characterise the transfer and appropriation of technology; the cross-national process of technological circulation regarding road construction and the role of actors and networks as agents of change are the main theoretical starting points of the analysis. In this context, the paper is organised in three parts. The first one relates road infrastructure construction in Greece to other national traditions. The second narrates the chronicle of the contract, while the third canvasses its spatial implementation.

Yuji Hoshino, Sachiko Okada

Department of Civil and Environmental Engineering, Graduate School of Science and Technology, Kumamoto University, Kumamoto City, Japan

Daijiro Kitagawa

The Agency for Cultural Affairs, Tokyo, Japan

Historical Research for the Planning and Construction of Misumi Port

The port of Misumi is one of the oldest Japanese modern ports, built by the initiative of the Meiji government. In spite of its historical importance chronologically speaking, the appreciations by historians are rather divergent: a beautiful masonry work realized thanks to the marriage of traditional and Western techniques, the badly selected site where commercial activities stagnate with the passing of years, etc. In order to validly define the historical value of this realization, this paper analyzes the archives, known or not, and clarifies the process and the ideas of the planning and construction of this port.

Sessions

Thursday 5 July, 11:30-13:00 LA VILLETTE SITE

- 303. Transfer of Knowledge, Colonial Situations 2
- 304. Rules & Standards, Specifications
- 310. Technical Literature, Publications
- 314. Deconstruction & Reconstruction
- 316. Reinforced Concrete, The Hennebique Companies
- 317. Metal Structures 1

Thursday 5 July, 14:00-19:00

Visits [TBC]

CNAM Central Library: Roof Framing & Collection
Concrete Roofs in Reims: Boulingrin Hall & Cathedral
Constructing Other Worlds: Désert of Retz and Aqueduct
Constructive History in Saint-Denis: Reserves of the CNAM & Basilica
Exploring Structure at the Louvre: Apollo Gallery & Carousel Arch
In Construction: Jean Bouin Stadium & Louis Vuitton Foundation
Innovative Construction: Maison de Verre & Saint Pierre de Montmartre
Metal Framed Churches: Saint Eugène-Sainte Cécile, Sainte Marguerite, Notre-Dame de Travail
Observing the Paris Observatory
On the Traces of Roman Paris: Frigidarium, Lutetia Arena, Archeological Crypt
Renovation in Progress: BnF Richelieu & Hôtel des Monnaies
Urban Renewal: Paris Rive Gauche & Freyssinet Hall
Versailles Château Roof Framing: Chapel & Opera
Versailles: Hydraulic Networks & Cathedral Roof Framing

303. Transfer of Knowledge, Colonial Situations 2

Chair: **Margareth Da Silva Pereira**, Universidade Federal do Rio de Janeiro, Brasil

Jorge Galindo Díaz

Universidad Nacional de Colombia, Manizales branch, Manizales, Colombia

Barbetti Serafín: Builder of Vaulted Bridges in South-Western Colombia [c. XIX]

During the second half of 19th century, in southwest Colombia, at least 30 arch bridges were built in brick, a complex structural typology that doubtless required an ensemble of specific technical knowledge for its execution. How was it carried out and was there one constructive tradition able to reach a maturity that allowed the achievement of works of significant importance? Through an investigative process that combined field work and documentary archives research, it was determined that the origin is in the figure of an Italian priest who arrived to Popayan City in 1859, and whose practical teachings to workers and local foreman served as a base in a process of singular technology appropriation. Through the historiographic report of the work of Serafín Barbetti and the analysis of his work positioning it among the technical culture of his epoch, his role was determinant as a transmitting agent of knowledge and the adaptations that made it successful. This work is framed in an investigation intimately connected with the history of the constructive technique and its mechanisms of assimilation and diffusion.

Hsin-Yao Hsu

Graduate School of Engineering, University of Tokyo, Japan

On the Construction Process of Government Buildings in Taiwan during the Japanese Colonial Period, 1895-1945

Most research concerning the modernization process of architecture in Taiwan during the Japanese colonial period tends to focus on the architects' ideas and the transformation of the "architectural style." In light of this, this paper shifts the focus of study to the "construction process" of government buildings that were the main constructions first performed under the "modernized" construction system. The purpose of this study is to try to shed light on the mutual interaction among all involved participants in the entire course of a building project, by analyzing the construction records retrieved from the Archives of the Bureau of Monopoly of the Taiwan Government-General. A conclusion can be generalized that with greater power given on the construction site, the supervisor became the most crucial person in the

building construction, which has consequently led to a construction site supervisor-based realization of design in the transitional period of modernization in Taiwan.

Hélène Vacher

ENSA de Nancy / HTTP-CNAM, Paris, France

Research and Construction in the Late Colonial Settings: Institutions, Technology and Development Programs in Africa, 1948-1958

Within the economic-development scheme for the French Union territories in the wake of the Second World War, a Committee for Overseas Housing was set up. Tasked with giving practical advice on the Modernisation Plan, the advisory body was allocated important funding for research and fed its expertise with the exchange of ideas and knowledge on an international basis. Though not unprecedented, the research in building construction for "tropical countries" became a new challenge as the development of French Overseas Territories was linked to post-war reconstruction in France in the 1950s. This paper focuses on technical bodies of the French administration in France and in the overseas territories and networks of engineers, architects and civil servants aimed at developing standards for construction overseas, including materials, technologies, methods and cost operations, while fostering specific building research as well as markets for building industries.

304. Rules & Standards, Specifications

Chair: **Brian Bowen**, Georgia Institute of Technology, USA

Beatrice Maria Fracchia

Politecnico di Torino, Italy

History of Construction in the 18th Century through the "Istruzioni" Written by Filippo Juarra

Filippo Juarra's works are documented in "Istruzioni" [instructions], which prove the existence of a technological culture developed in the 18th century. The term "instruction" refers information issued by the First Architect who was in charge of all the architectural works commissioned by the House of Savoy. The content of this information highlights skills and practices of the entities involved in the technical aspects of construction sites. The instructions outline the relationships between professionals and workers on the site and they give us an insight into Juarra's planning skills and his construction techniques. The "Istruzioni" always contain sketches and drawings that complete the written description of buildings to be constructed on the site. These are useful in explaining Juarra's technical writings and drawings. This study is an essential aid in understanding the techniques that characterize the history of constructions in the 18th century.

Katie Lloyd Thomas

Newcastle University, UK

Describing Construction: Building Specifications and the 'Process-Based' Clause

This presentation explores the description of construction and materials in United Kingdom building specifications. Although there is some acknowledgement that a range of forms of description are used in specifications, the differences between them and the conditions which give rise to the various forms has yet to be investigated. Here, I focus on the 'process-based' clause, which details how materials and construction elements are to be made up. This form of specification appears in the late 18th century and reaches its peak in the 1960s before, with the rise of performance specifications, descriptions of process almost disappears, and this form of knowledge is no longer available. While to some extent the use of one form of clause over another is informed by the kind of material or process being prescribed, selection is largely determined by more general shifts in procurement, manufacture and contractual organisation. The history of construction, then, shapes the documents through which that history can be known.

Jeroen Cornilly

Catholic University of Leuven, Belgium

Contractors of 19th Century Public Works in Belgium: Looking for a Research Approach for the Rural Areas

In the course of the 19th century, public works strongly altered the image of Belgian villages. Rural communities outsourced their construction works to the private sector. Although not legally obliged, works were generally put up to public tender. In this practice, building specifications became crucial documents in the relation between the public client and the contractor of public works. The specifications also indicate that the contractors of public works in rural areas had to be able to execute the totality of the building project and that they weren't necessarily recruited locally. They appear as a heterogeneous group of local craftsmen and general contractors, located in the city as well as in the countryside.

310. Technical Literature, Publications

Chair: **Javier Girón**, Universidad Politécnica de Madrid, Spain [TBC]

Dermot O’Dwyer, Ronald Cox

Department of Civil, Structural and Environmental Engineering, Trinity College Dublin, Ireland

George Semple and the Reconstruction of Essex Bridge in Dublin 1753-1755

George Semple’s *A Treatise on Building in Water*, in which he described the reconstruction of Essex Bridge across the river Liffey in Dublin, is among the earliest civil engineering texts published in English. Semple reconstructed Essex Bridge in the early 1750s but did not write his account of the reconstruction until 1775. Semple’s treatise reveals construction practice in Ireland and England in the mid-18th century. The text is well illustrated, includes details of the construction equipment and gives detailed technical information in a number of areas.

Semple’s treatise also reveals the flow of technical information between Ireland, England and France at this time. The traditional architectural texts of Alberti, Palladio, Scamozzi and Serlio did not provide Semple with the technical advice he needed, nor did visits to Labeledye and others in England. Semple was unfamiliar with French. However, the illustrations in Belidor’s *Architecture Hydraulique* [1753] and a perspective drawing of the construction of the Pont d’Orleans guided his construction of the cofferdams required to construct the new foundations for the bridge.

Christoph Rauhut

Institute of Historic Building Research and Conservation, ETH Zurich, Switzerland

Handbooks on Construction Site Supervision in the 19th Century

In the 19th century typical building processes changed as a result of new and modified materials and building techniques; moreover, specialised craftsmen were increasingly required to execute work on construction sites. At the same time the process of scientification initiated within the polytechnic schools was transforming the structure of knowledge on building. The genre of handbooks on construction site supervision – novel for the time – reflects both developments. Sixty different German books on construction site supervision from the 1840s to the 1910s form the body of research in this field. The aim of these books was to give guidance on an increasingly complex building process by providing the necessary knowledge in a useful, but orderly form. The aim of this paper is to dwell on these books to discuss their origins, their aims and usefulness,

their dependency on the ‘Praxis’ and their inherent constraints.

Emmanuelle Minault-Richomme

Bibliothèque du CNAM, Paris, France

The Conservatoire Numérique: A Reservoir of Digitized Resources for Construction History

The purpose of this paper is to present the Conservatoire numérique [Digital Conservatory], that is to say the online heritage library of the Conservatoire National des Arts et Metiers, founded in 2000. The library now has 600 titles in French on the History of Science and Technology, published from the 16th to the 20th centuries. The CNUM allows the consultation of scholarly journals, catalogs of manufacturers, encyclopedias and monographs organized in thematic corpuses such as world fairs, *théâtres de machines*, electricity, construction history, etc... Thus, about a hundred books on construction history have already been digitized and put online, illustrating techniques for shaping territories, cities and architecture.

314. Deconstruction & Reconstruction

Chair: **Stéphane Büttner**, Centre d’études médiévales d’Auxerre, CNRS / Université de Bourgogne, France

Philippe Bernardi

CNRS-Lamop UMR 8589, Paris, France

Daniela Esposito

Dipartimento di Storia, Disegno e Restauro dell’Architettura, Sapienza-Università di Roma, Italy

For a History of Deconstruction

Deconstruction, in a city, primarily appears as an indispensable step in the preparation of the site. Whether it is about constructing “something new” or simply modifying the building, the existing structures have to be fully or partially demolished, which cannot be done haphazardly. Considered in terms of disassembly, this operation is a source of materials and a prelude to recovery, which is recalled, in its own way, by the medieval expression “château abatuz est demi refez.” We intend, with the study of textual and iconographic sources collected for the last centuries of the Middle Ages, to have a closer look at this somewhat obscure phase of the constructive process. In opposition to an image of unbridled, blind vandalism, from such sources it seems possible indeed to propose a more “sensible” vision of deconstruction, which accounts for its technical nature.

Nick Beech

Bartlett School of Architecture UCL, London, UK

Rescue, Recover! The demolition industry and its relationship to the London County Council Architect’s Department in the Second World War

At the outbreak of the Second World War, the London County Council [LCC] Architect’s Department mobilized to lead rescue and recovery operations. In this task, the Department drew on the manpower and expertise of the demolition industry. This collaboration had dramatic, transformative effects. A dispersed, informal and under-represented industry before the War, by its close the industry had federated and integrated heavy plants, its labour force beginning a process of unionization, clarifying pay and skills structures. This paper argues that certain features peculiar to demolition can be traced to the forms of commercial-state contracts, training, and allocation of risks and responsibilities undertaken with the LCC during the Second World War. This paper utilises sources in LCC and other archives, providing examples of contracts, quantitative data on materials and labour deployed, administrative accounts and personal testimony of the structure, practices and training of demolition in London during the War.

Richard Burt

Auburn University, Auburn, AL, USA

The Builder’s Flying Squads: An Analysis of the Ministry of Works Special Repair Service Activities during WWII

The United Kingdom government’s Ministry of Works Special Repair Service is an excellent example of how builders made a significant contribution during WWII. The duty of the Special Repair Service was the repair of homes damaged by bombing. Working from depots throughout the country, repair units and “Flying Squads” of 100 or 60 men consisting of several different trades, under the supervision of surveyors, superintendents and foremen, would travel in special equipped vehicles to areas recently bombed. The duty of the flying squads was to carry out first-aid repairs in order to make homes fit for occupation. In order to accomplish this, a minimum repair standard was established. The records of the Ministry of Works held in the United Kingdom National Archives provide the data to identify how the flying squads were organized, composed, equipped and supported. Photographic, audio and film resources at the Imperial War Museum provide a more intimate picture of what life was like in a flying squad. Sources from several local archives provide additional information.

316. Reinforced Concrete, The Hennebique Companies

Chair: Paul Acker, Lafarge, France

Hermann Schlimme

Bibliotheca Hertziana, Max Planck Institute for Art History, Rome, Italy

François Hennebique's Patents as Applied on the Building Site: The Mercato Orientale in Genoa [1896-1899] and the Creation of a Local Construction Network

This paper deals with François Hennebique's patents for reinforced concrete dating from 1892 and the later supplements made to them. Applying the methodology of an epistemic history of architecture and basing this study on the Mercato Orientale [1896–1899] and other Genoese structures by Hennebique – all of which were created under the direction of the licensee Giovanni Antonio Porcheddu – an investigation will be made of what it means to build according to a patent and what epistemic processes took place in establishing a patented technology on site. One aim, for example, was to reduce to a local context Hennebique's mode to conduct international projects by correspondence. In the construction of the Mercato Orientale, local value-added chains – from the planning, through the construction workers to the supply of materials – were activated. The present paper will also examine how the relationship between form and construction was resolved for the Mercato Orientale.

Mónica Silva-Contreras

Universidad Iberoamericana, Mexico City, Mexico

Béton Armé in a Sinking City: Mexico 1902-1914

The use of reinforced concrete during the first decade of the 20th century is an important topic in Mexican architecture, especially considering that the first experiences with the material in Mexico City were contemporary with significant structural tests made in Europe and some other places by Hennebique representatives. Performance of new materials in earthquakes, such as new foundation systems, was important for Mexican builders, since the city stands on an ancient lake. Foreign technologies were in their hands to use them according to their own local needs. Besides technical issues, modern construction in Mexico had to handle within the Spanish building tradition. The attempts to build in a national style in architecture diverged with the proportions of the reinforced concrete structural elements. It was noticeable during the works for the Escuela Nacional Preparatoria, where the Hennebique system was used to achieve the longest

reinforced concrete beam of that time in Mexican architecture.

Stephanie Van De Voorde

Ghent University / Centre for Flemish Architectural Archives [CVAA], Antwerp, Belgium

Rika Devos

Ghent University / University College of St. Lucas Architectuur, Brussels, Belgium

The 'Scientification' of Reinforced Concrete in Belgium during the Interwar Period: Development and Dissemination of Scientific, Theoretical and Technical Knowledge

Through the work of François Hennebique, Belgium played an important role in the early history of reinforced concrete, yet forfeited this pioneer position when the theoretical dimension of the material was to be developed. Before World War I, Belgium contributed little to the theory of reinforced concrete, especially in comparison with nearby countries. It was not until the interwar period that the 'scientification' of the material did gain momentum in Belgium. Yet, despite the late start, impressive headway was made during the 1920s by Belgian engineers and industrials in various fields: regulations; theoretical knowledge in academia, laboratories and professional organisations; specialized press; international conferences. This paper presents a detailed and critical analysis of this scientific activity and illustrates how the various fields were developed simultaneously and, consequently, interacted and strengthened each other, most often through the wide involvement of a rather concise number of engineers, scientists and contractors.

317. Metal Structures 1

Chair: Werner Lorenz, Brandenburg University of Technology, Germany

Lara Slivnik

Faculty of Architecture, University of Ljubljana, Slovenia

A Prefabricated Cast Iron Three-Hinged Arch Bridge in Ljubljana

This paper is an overview of the Hrdecky Bridge [1867] across the River Ljubljanica in Ljubljana, the first three-hinged arch bridge built in the Habsburg Monarchy and the oldest three-hinged cast-iron bridge in Europe [excluding the British Isles] still in use. The supporting structure is a prefabricated three-hinged arch with a total span of 30 m. It is made of cast-iron pipes that are joined together with screws to make one cantilever truss. Three cantilevers from one side of the bank are connected together with I beams and linked up with another three cantilevers from the opposite bank. Both groups of cantilevers are joined together at the crown of the arch with hinges. The prefabricated structure of the bridge permitted it to be moved three times to three different locations, each time bearing the same name, i.e., the Hrdecky Bridge.

Volker Wetz

Brandenburg University of Technology, Cottbus, Germany

Historic Bridge Bearings: Material Research on Cast Steel

This paper gives a review of the history of cast steel and presents results from material analyses performed on sliding bearings from the first decade of the 20th century. All bearings were made from cast steel, which had become the material predominantly used for bridge bearings by the end of the 19th century. The analyses provide insights into the metallurgical development for the practice of casting steel at the turn of the 20th century and yield a broader and more reliable base for the structural assessment of historic bearings still used in historic bridges.

Bernard Espion

Université Libre de Bruxelles, Belgium

The Vierendeel Bridge at its Heyday: Rational Design, Experiments and Brittle Failure

The purpose of this paper is to document the evolution of the Vierendeel Bridge, from its inception in 1896 up to its heyday in the 1930s. The use of this kind of bridge, mainly in Belgium and Congo, matured very slowly between 1902 and 1930. However, the number of Vierendeel bridges increased very rapidly with the construction in Belgium, between 1932 and 1937, of more than 50 spans in steel, mainly welded. This was certainly favoured by extensive research efforts in Belgian universities with the structural analysis of this kind of girder and on the welding mode of the connection of steel elements. But the fast introduction of the new welding technology in bridge steelwork building led to the failure of the Hasselt Bridge in 1938 and to serious damages to at least two other Vierendeel type bridges in 1940. These accidents mark traditionally the beginning of the brittle failure story.

Keynote Lecture

Friday 6 July, 9:00-10:15 MALAQUAIS SITE [AMPHI BINET]

Antonio Becchi

Max Planck Institute for the History of Science, Berlin, Germany

Looking for an Equilibrium Point: A Moonwalk with Vitruvius and Gyro Gearloose

The talk investigates the ideas of 'invention' and 'equilibrium' in construction history, with particular focus on Vitruvius' *De architectura* and on the Vitruvian tradition. We follow the historic evolution of two notions that encapsulate the tension between the attractiveness of 'artistic' liberty and

the rigor of 'scientific' method. The history of construction includes a rich collection of ideas and debates on this topic: this talk presents some examples of the role played by *ratio*, *cogitatio*, *inventio* in the evolution of the *idée constructive*.

Sessions

Friday 6 July, 11:00-13:00 MALAQUAIS SITE

- 407. Applied Sciences 2
- 408. Structural Analysis & Modeling 2
- 419. Management of the Construction Site
- 421. Institutions
- 428. Mortar
- 429. Reinforced Concrete, Reception & Dissemination
- 435. Wood Structures 2
- 438. Interior Environment, Heating

407. Applied Sciences 2

Chair: **Antonella Mastrorilli**, ENSA de Lyon, France

Alberto Grimoldi

Politecnico di Milano, Italy

Guarini's Flat Vaults and Thin Vaults on Wooden Beams in the Duchy of Modena

Guarino Guarini repeatedly insisted upon the originality of his own contribution on vault construction. Recent literature has generally confirmed his claim. However, less attention has been paid to the fact that he codified and improved construction techniques that were already very common and popular in northern Italy. His “flat vaults” and thin vaults on wooden beams in the Duchy of Modena – where Guarini came from – and Emilia offer a significant example. They clearly reflect a ‘know-how’ acquired with time, since the 16th century when more and more alternatives to timber floors were frequently proposed. In the same buildings – as in Correggio – it is possible to find flat vaults and more complicated and sophisticated versions of light vaults, built before 1730. In Guarini’s work this dualism arrived at a better synthesis, an original and cultured expression and, therefore, rightfully “my own method.”

Carlo Bianchini

Dipartimento di Storia, Disegno e Restauro dell’Architettura, Sapienza-Università di Roma, Italy

The Role of Stereotomy in Guarino Guarini's Space Research

This paper presents the work of Guarino Guarini in the fields of Stereotomy and Representation Geometry. Beyond his activity as an architect, in fact, Guarini should be considered as a versatile intellectual who discussed the above topics in two books [*Euclides adauctus* and *Architettura Civile*] which are complementary and together represent part of a modern Descriptive Geometry Treatise. In the former, Guarini discusses the fundamentals of geometric representation which, in the latter, become the tools for solving the problems of accurate intersection and unfolding concerning cylinders, cones, spheres, conoids and other solids. This is why Guarini’s role should be considered one of the most relevant in the field of 17th century science, especially in that of Representation Geometry. In fact, his way of explaining and using orthogonal projections should be considered as a mature codification of common, well-known “technical” proceedings rather than a simple anticipation of Monge’s method.

Andreas Kahlow

University of Applied Sciences Potsdam, Germany

Theory and Practice in Timber Construction 1800-1830

The evolution of the theory of structures has a missing link: its relationship to practice in the first three decades of the 19th century. The publication of scientific literature about the theory of structures intensified in the years around 1800 and shortly afterwards. Bridge building is the forerunner and leads to the elaboration of new methods in dimensioning. Using archival material about the Berlin Bauakademie in the 1820s, this paper will show how, under the leadership of Johann Albert Eytelwein, new concepts of a theory of structures were firstly fully applied in teaching. The newly appointed professor Johann Friedrich Wilhelm Dietlein put the approach of uniting beam statics and theory of elastica into practice. He gave examples of sizing wooden structures as for instance in bridge calculation, bending of simple and continuous beams, and buckling. Eytelwein’s experimental data gave the basis for a safety concept.

Federico Focè

Dipartimento di Scienze per l’Architettura, Università degli Studi di Genova, Italy

Same Title, New Contents: Saint-Venant's Revised Edition [1864] of Navier's Résumé Des Leçons Sur L'application De La Mécanique [1826, 1833]

Following previous papers on Saint-Venant’s early unpublished studies of applied mechanics, elaborated during 1837-1853, this paper will be devoted to the improvement given by Saint-Venant to the third edition [1864] of Navier’s *Résumé des leçons ... sur l'application de la mécanique*, first published in 1826 and reprinted in 1833 with few additions by Navier himself. Despite the great importance of Navier’s treatise and its international success, a comparison of the original textbook with Saint-Venant’s ‘revised’ edition shows the limits of the former through the advances of the latter. For the first time in the history of structural mechanics, Saint-Venant was able to transfer the fundamental results of the mathematical theory of elasticity from the specialized journals read by few scholars to the world of practical engineering. This paper will offer a synthetic sketch of this contribution, which still represents an exemplary case of the interaction between pure and applied sciences.

408. Structural Analysis & Modeling 2

Chair: **Bill Addis**, Co-Editor, Construction History, UK

Jacques Heyman

University of Cambridge, UK

The Membrane Analysis of Thin Masonry Shells

The stresses in masonry are usually very low compared with the basic strength of the material. Thus the analysis of a masonry structure is concerned primarily with the determination of a pattern of forces to equilibrate the known loading, and hence to estimate the required strength of supports – to find, for example, the thrust of a high vault, and hence the values of the loads imposed on the buttressing system. This paper is concerned with the use of the equations of membrane theory to analyse such vaults. These equations show that there is a profound difference in the behaviour of domes and fan vaults. In particular, they indicate that a masonry dome can be relatively simple to construct, whereas a fan vault requires elaborate centering to support the masonry until a whole bay is complete.

Timothy Cooke, John Ochsendorf

Massachusetts Institute of Technology, Cambridge, MA, USA

The Temple of Diana at Baiae: History and Structure of an Imperial Roman Dome

This paper examines the construction and structure of the Temple of Diana, a second century A.D. Roman dome forming part of the extensive thermo-mineral bathing complex at Baiae. This structure holds significance in the history of concrete construction and, specifically, domed structures due to its roughly ellipsoid profile, an uncommon form in Roman construction. This paper develops a hypothesis for the creation of the dome geometry by the builders. In addition, the first structural analysis of the dome is used to quantify the relation between geometry and stability. By testing various alternative models, the paper identifies a possible collapse mechanism due to insufficient buttressing on one side of the dome.

Alejandra Albuerne, Martin Williams

Department of Engineering Science, University of Oxford, UK

Janet Delaine

Faculty of Classics, University of Oxford, UK

On the As-Built Geometry of the Vaults of the Basilica of Maxentius

The present paper studies the geometry of the remains of the Basilica of Maxentius, built in Roman concrete in the early fourth century. The deformations of the barrel vaults are studied, and the geometry of the collapsed cross vaults is reconstructed from the remains [springings and broken fragments]. The purpose of this work is to gain a further understanding of the Basilica from a structural engineering point of view: in order to perform a meaningful structural analysis, an accurate reconstruction of the original geometry is needed. Some initial structural assessment has been performed on the studied geometries.

Maurizio Brocato, Lucia Mondardini

GSA-ENSA Paris-Malaquais, France

An Insight into Abeille's Flat Vault through Numerical Analyses

We present a study of Joseph Abeille’s flat vault [1699], based on numerical structural analyses, aiming at solving the ambivalence that such a system reveals relying statically partly on thrusts [or on the principle of the inverted catenary], partly on bending [or on the principle of the lever]. Analyses were made comparing the outcomes of several geometries within three one-parameter families: i) structures made with bulky/slender blocks; ii) structures made with steep/gradual contact slope; iii) thick/thin structures; span, boundary conditions, materials and loading being equal for all members of each family. Aspects appear of the statics of these vaults not highlighted previously. Due to their chirality, the thrust is a chiral system of forces, having – in addition to the standard component normal to the vault’s edge – a tangential horizontal component. Bending prevails on thrusting, a result not supporting the idea that Abeille’s vaults can be seen as sets of interwoven flat arches.

419. Management of the Construction Site

Chair: **Arnaldo Melo**, University of Minho, Portugal

Raúl Romero Medina

Universidad CEU-Cardenal Herrera, Valencia, Spain

Manuel Romero Bejarano

Universidad de Sevilla, Spain

Building during the War of Granada: The Project for Reconstructing Fuengirola in 1485

In 1485 the Castilian troops conquered Fuengirola [Malaga]; it was then that the Catholic Monarchs commissioned the reconstruction of both the bastion and the town walls of the city of Jerez de la Frontera [Cadiz]. The local authorities sent a committee to evaluate the cost of the works in question, and a report with all the details was written. The information included in this document has allowed us to envisage those parts that needed to be reconstructed – using the formwork technique in the majority of cases. Furthermore, the record provides also detailed information with regard to the number of workers, materials, tools and specific utensils. The reconstruction was not carried out in the end due to financial problems, and the population in Fuengirola decreased dramatically; it was not until contemporary times that the area was populated again. The report gives us a clear idea of the way in which Christian buildings were edified by the end of the War of Granada and also of the manner in which Christians faced the Muslims using Moorish architectonic arms.

Catherine Isaac

Université Toulouse II – Le Mirail, France

Reconsidering the “Considerable Expense” Involved in Building the Lavour Bridge in Languedoc [1769-1791]

In 1782, Jean-Rodolphe Perronet [1708-1794], Director of the École des Ponts et Chaussées, criticized the “considerable expense” involved in building the bridge in Lavour [1769-1791] in Languedoc, a region that retained its administrative autonomy. This communication, stemming from Perronet’s remark, aims to identify and analyse the reasons for such expenses, and put them into perspective. After an overview of the historical details, we will try to identify what paved the way to such cost overruns, the working methods of engineers and contractors, their relationship and their links with the local authority in Languedoc, to establish comparisons with other French regions. Finally, by focusing on Perronet’s remark and placing it in the context in which he made this

criticism, we will try to point out how much it reveals about the balance between a likely aspiration to magnificence and some kind of economic efficiency.

Kenneth F. Robson

University of Oklahoma, Norman, OK, USA

Managing the Design and Construction of the Empire State Building: Are There Lessons for Today’s Projects?

Opened on 1 May 1931, the Empire State Building was the tallest building in the world for more than 40 years. In 20 months the building was designed, engineered, permitted, demolition completed and the building constructed. The innovative construction methods and techniques employed to construct the building are well documented and were important aspects in the speed of construction. The innovative construction methods were part of an overarching management process – a process that emphasized teams and encouraged innovation. The management processes of the Empire State Building can be tied directly to the management theories developed during the careers of the key players who owned, designed and built the Empire State Building. A study of the management processes and the innovative thinking allowed through the use of these management processes and the emphasis on teamwork can provide lessons to the owners, architects and contractors of today’s complex construction projects.

Camilo Villate, Brando Tamayo

University of Los Andes, Bogota, Colombia

The Avianca Tower: Practices Driving Technical Innovations in a Construction Firm in the 60s

The modernist construction industry in Bogota presented management practices and high rates of innovation that are being rediscovered in current times. This paper studies the case of the Avianca office tower [1969], which was designed and built by Esguerra Saenz Urdaneta and Samper in alliance and partnership with other organizations, which also produced a building with high-impact technical innovative features. This case study describes not only the technical innovations made, but also explains the conditions that allowed them to happen from an organization, technology, employee, market and knowledge perspective.

421. Institutions

Chair: **Tricia Meehan**, ACS-ENSA Paris Malaquais / UIUC-SAPV, France

Malcolm Dunkeld

London South Bank University, London, UK

The Great Hall of the Institution of Civil Engineers Headquarters Building

This paper focuses on a single building profession – the Institution of Civil Engineers – and considers how the institutional headquarters building located in Great George Street, London SW1, visually represents the authority of the profession and what meaning can be given to the ‘things’ or ‘paraphernalia’ contained inside. A relatively large number of primary sources can be found in the ICE archives on the design and construction of the headquarters building. These include original drawings, specifications, tender documents, correspondence, accounts, Building Committee and Council minutes, all made available by a welcoming and knowledgeable library staff. The paper considers the Great Hall of the Institution building and forms part of a wider study of the building that will be published shortly.

Christiane Weber

Karlsruhe Institute of Technology, Germany

Volker Ziegler

Universitätsarchiv Stuttgart, Germany

Construction Material Testing at MPA Stuttgart during the Third Reich

In 1884, the Institute for Materials Testing was established by Carl Bach, professor of Mechanical Engineering at the Stuttgart Polytechnical School. Under Richard Baumann and Otto Graf the Department for Materials Testing quickly developed into one of the most important institutions of this kind in Germany. Since the 1920s, Otto Graf’s role in that institution continuously increased. This contribution illuminates where and in what context the engineers of the Institute for Materials Testing were involved in national socialist planning. It therefore draws on material treasured in the Universitätsarchiv Stuttgart.

Alicja Gzowska

Institute of Art History, University of Warsaw, Poland

An Institution for Structural Innovation: Office for the Study and Design of Industrial Building Types [BISTYP] in Postwar Poland

In post-war Poland, during a time of particular political,

social and economic circumstances an unusual design office was created which gathered the best Polish structural designers. The Office for the Study and Design of Industrial Building Types [BISTYP] enabled the ambitious constructors and researchers a multilateral development opportunity by supporting and encouraging them to conduct research, experiment and implement the newest structural technologies in practice. A broad scope of issues and the atmosphere of close and creative cooperation with architects resulted not only in numerous interesting and innovative construction solutions for industrial objects, but also in spectacular public buildings, which thanks to their exceptional formal and construction qualities quickly gained appreciation. This paper offers an insight into the conditions and labour organisation of the BISTYP.

Ana Paula Koury

São Judas Tadeu University, São Paulo, Brazil

Brazilian Construction Center: Initiative for Management of the Brazilian Housing Construction Industry [1969-1972]

The current paper presents the creation context, objectives and actions of the Brazilian Construction Center [Centro Brasileiro da Construção], an institution geared towards the management of the Brazilian housing construction industry. The initiative, composed of technical institutions, plus industrial and financial sectors, allowed for a coordinated action performed by major players involved in civil construction oriented towards large-scale housing. This perspective was introduced mainly on account of the creation of the National Housing Bank [Banco Nacional da Habitação] in 1964. The study of this initiative allows us to revisit the part played by the state, class institutions, private enterprises, and technical staffs, with the objective of re-proposing the technical innovation agenda oriented to solving the housing problem, thereby contributing to building economic development and social alternatives within a context of returning to a nationwide development project led by the Brazilian state.

428. Mortar

Chair: TBA

Frédéric Davidovits

Geopolymer Institute, Saint Quentin, France

Geological Origin of the Reagents Constituting Roman Mortar, According to Vitruvius

It was established that the volcanic sands, around Rome, have physical properties that make them correspond to the *harenae fossiciae* described by Vitruvius [II, 4]. However, Vitruvius states that the best of all sands extracted from volcanic tuffs is what he calls the tuff *carbunculus* “carboncle” or *materia excocta*, which is a “soft volcanic tuff calcined by underground fire.” He also claims that it is found geologically in Etruria, in the volcanic area located to the north of Rome. Vitruvius uses this volcanic sand exclusively for concrete masonry, whereas regular pozzolana from Napoli [*pulvis*] is especially employed for marine piers. He described, as a geologist, the formation of construction materials starting from volcanic fire and, as an architect and engineer, the reasons for which the volcanic reagents react so well with lime. Thus the volcanic tuff *carbunculus* refers to a pyroclastic rock traversed by degassing pipes, called “fossil fumaroles.”

Reinhard Heinz

Vienna, Austria.

The First Verifiable Application of Cast Mortar in Prefabricated Construction in the Coffered Ceiling of the Early Hellenistic Mausoleum of Belevi

The Mausoleum of Belevi is the first known example of the use of filling mortar in masonry in connection with *opus revinctum*. The coffered ceiling was constructed of ashlar masonry, which had been pre-fabricated on the ground. The offsetting of the blocks, and their dowelling, was only possible when free space was preserved at the backs of the blocks, allowing their installation and the grouting of the dowels. The interstices weakened the masonry structure and were therefore filled in with poured mortar. This mortar guaranteed, together with clamps and dowels a shear rigid ceiling construction. Cavities in the ceiling structure relieved the construction. These principles are still applied today, for example in hollow core slabs, whose elements are connected to a constructive unity with a circumferential grid, and where the weight is reduced by means of cavities. The application of such a mortar jointing technique is first evident at Belevi.

Barbara Thuswaldner

Institute of History of Art, Building Archaeology and Restoration, Department for History of Architecture and Building Archaeology, University of Technology, Vienna, Austria

The Use of Mortar in Late Hellenistic Construction: The Case of the Octagon in Ephesus

The use of mortar in combination with ashlar masonry during the Hellenistic and Roman period has been considered uncommon. The recent study of a tomb monument in Ephesus shows that probably mortar was already used in late Hellenistic times as a leveling course as well as an ashlar binding material. The technical construction of the walls of the cella was analysed by using a virtual stone by stone reconstruction of the entire building, which was compiled from 3D models of all remaining building blocks. According to the evidence derived from this reconstruction it seems very likely that mortar was used as a leveling course in its ashlar masonry. This paper will address these unexpected findings and furthermore tries to depict that mortar was also used in the context of various Late Hellenistic and presumably even older buildings due to efficiency reasons within the construction process.

Marco Cofani

Politecnico di Milano – DiAP, Italy

The Knowledge and the Development of Mortars between the 18th and 19th Centuries: The Case-Study of the Verona Amphitheatre Restoration

The city of Verona, between the end of the 18th century and the first half of the 19th century, was the scene of a large, vibrant scientific debate concerning building materials and, in particular, the so-called *ciment romain*. This debate is well recorded in the archival documentation related to the maintenance and restoration works of the Arena amphitheatre. Many documents have an exceptional precision in language and quantitative data: this opens new possibilities of knowledge about historical mortars, whose composition is often subject to cases where many variables remain undetermined. The study has also highlighted important information about the diffusion of scientific knowledge and the new “chemical” attitude of those who worked for the development of innovative, “better” mortars, used in particular to fill the joints between the stone steps of the cavea in order to preserve the underlying vaults of the Amphitheatre from the infiltration of rain.

429. Reinforced Concrete, Reception & Dissemination

Chair: Thomas Leslie, Iowa State University, USA

Cédric Avenier, Anne Coste

Laboratoire Cultures constructives, ENSA de Grenoble, France

Auguste Perret: The Grenoble Orientation Tower – Architecture, Art and the Press

The Orientation Tower of Grenoble is an important project in Auguste Perret’s career and also in the history of cement and reinforced concrete in France. The reinforced concrete tower of Grenoble was designed and built by August Perret for the 1925 International Exhibition on hydroelectric power and tourism. The main goal of this paper is to explain the way in which Auguste Perret was awarded the contract for this project and why it is one of Perret’s favourite works, the first building he erected as an architect. This paper shows the particular role of art and literature critic Marie Dormoy, his mistress, at this particular stage of the architect’s career. It also shows the link between this project and the conferences on concrete and architecture that Auguste Perret gave at this time.

Edoardo Currà

Department of Civil, Building and Environmental Engineering, University of Rome Sapienza, Italy

Manual Abilities and Modern Constructive Techniques in a Building by Arturo Hoerner: The S. A. Supertessile Plant and the System Baroni-Lüling, Rieti-Italy, 1926

The study of the Supertessile complex at Rieti has brought to light the application of the Italian Baroni-Lüling patent and some of its effects on the development of constructional techniques in reinforced concrete, especially in the field of the planning and construction of light components for large covered structures. A notable impulse towards the rationalization of construction can be attributed to this system and to its applications by the firm ing. H. Bollinger. Above all, this came about through the innovative system of spacing the reinforcement bars with bolts, to create semi-rigid reinforcement lattices. This application was employed in all of the pavilions of the Supertessile plant, perfectly integrated with the architectural solutions of the architectural designer Arturo Hoerner. His plan reinforces certain invariants shared by modern architecture; for example, a plan simplified of ornament and qualified through the geometry of the construction, which found the ideal technique in reinforced concrete.

Andrew Rabeneck

Imperial College, London, UK

The Transformation of Construction by Concrete

Concrete is used as a case study to explain fundamental transformations in construction during the 20th century from a universal craft activity to a globalised industry.

Jesús Anaya Díaz

Universidad Politécnica de Madrid, Madrid, Spain

Reinforced and Prestressed Concrete in High-Rise Construction in Spain, 1950-1975: Technique and Innovation

The history of 20th century architecture is significantly linked to the emergence and evolution of reinforced and prestressed concrete. The creation of the pavilion and high-rise construction types will be the models for the development of contemporary architecture, widely known for their innovative adoption of new building materials and advanced construction techniques. The field in which an extensive evolution of structural and constructive types will be developed, was sustained on those prototypes, on scientific research on materials and on direct construction experience. As this happens, the production techniques of architecture kept changing.

The evolution of concrete at the beginning of the second half of the 20th century will have an impact on institutions such as the Spanish Association of Prestressed Concrete [AEHP] created in 1949, the International Association of Prestressed Concrete created in 1951, or the International Association of Laminar Structures [IASS] chaired by Eduardo Torroja from the Technical Institute of Construction [ITCC] and founded in 1959.

435. Wood Structures 2

Chair: James W.P. Campbell, University of Cambridge, UK

Zeynep Eres

Istanbul Technical University, Turkey

Eylem Özdoğan

Istanbul University, Turkey

A New Approach in Studying the Structural Systems of Prehistoric Wooden Post Buildings: A Case Study from Aşağı Pınar in Eastern Thrace

A preliminary assessment of the structural details of the Neolithic architecture discovered at the prehistoric site of Aşağı Pınar will be presented in this paper. The site, located in Eastern Thrace, is considered as one of the major archaeological sites in understanding the transmission of sedentary village life from its homeland in Anatolia to Europe, via the Balkans. In their original homeland, Neolithic communities developed the basic principles of architectural structuring, developing from round hut-like structures to multi-story rectangular buildings. In the area of its origin, the main building material was stone or mud-brick. But while this new way of life was expanding to the Marmara region, they had to adapt to a new habitat. In particular, the region where Aşağı Pınar is located is within the forest zone and the new settlers had to develop new building strategies using wood and wattle. From the setup of the ground plan to the roofing every structural detail had to be adapted to the new building material.

Dietmar Kurapkat

German Archaeological Institute, Berlin, Germany

A Roof under One's Feet: Early Neolithic Roof Constructions at Göbekli Tepe, Southeastern Turkey

The ongoing excavations at the site Göbekli Tepe in southeastern Turkey have revealed a number of monumental buildings, which were erected between the late tenth and early eighth millennium B.C. Some of these special buildings are much bigger than the usual Neolithic huts and houses and are equipped with monolithic T-shaped pillars. Not only for the history of construction but also in view of functional questions, it is an important matter of discussion whether these buildings were roofed or if they remained open to the sky. A detailed examination of all the archaeological data has led to the conclusion that most probably the buildings were covered by earthen roofs on wooden supporting structures. The key to the acceptance of this thesis is the convincing reconstruction of the construction design to span rooms of up

to nearly 20 m. diameter with the means of early Neolithic craftsmanship.

Alexandra Harrer

Tsinghua University, Beijing, China

Fan-Shaped Bracket Sets and Their Application in Different Building Materials: A Discussion of the Chinese Fangmu Tradition and Jin-dynasty Tomb Architecture in Southwest Shanxi Province

It is a well-known characteristic of “non-timber architecture” in China, such as stone bridges, pagodas adorned with glazed ceramic tiles, or brick tombs, that they imitated their timber counterparts in a different material. The paper discusses the application, function and reliability of such “quasi-architectural evidence” and raises the question of possible deviation and distortion of the wooden sample. It specifically addresses the thrilling phenomenon of “fan-shaped bracket sets,” an unorthodox construction method that has been popular in Central China, Shanxi province since the 11th century, and explores their reflection in the Jin-dynasty brick tombs of the Duan family in the southwest of the province. Whereas regular bracket sets usually consisted of bracket-arms that were perpendicular and parallel to the wall plane, such corbelled clusters added horizontally slanting brackets projecting at a 45 or 60 degree angle.

Christof Krauskopf

Brandenburg State Office for the Preservation of Monuments and Sites, Wünsdorf, Germany

Medieval Timber Structures in Eastern Germany: Archaeological Evidence from Eberswalde

Very few medieval timber-framed buildings survive in Brandenburg, the region around Berlin. The earliest known examples, which date to the 15th century, are from the town of Brandenburg on the Havel. New archaeological evidence is, therefore, of great importance to further research on medieval timber structures and building techniques. Eberswalde is built on waterlogged ground and well-preserved timber structures, dating from 13th century up until the 19th century, have been uncovered during excavations in the town. The analysis of over 1200 tree-ring dates has established an exact chronological sequence, and provided information about the lifetime of individual buildings and the reuse of timbers. The tool marks visible on many of the timbers, and the survival

of various joints and fixings, provide details of woodworking and construction methods. The sequence of dates shows that the development of the town was accelerated by margrave Albrecht III at the end of the 13th century.

438. Interior Environment, Heating

Chair: **Emmanuelle Gallo**, HTTP-CNAM / ENSA Paris-Belleville, France

Lynne C. Lancaster

Ohio University, Athens, OH, USA.

Heated Vaulting in Roman Britain and the Invention of Hollow Terracotta Voussoirs

During the last quarter of the first century A.D. in Roman Britain, a new type of bath heating system was invented that included hollow terracotta voussoirs creating hot air channels within the vault. The invention of the new vaulting method can be traced to a particular group of tile makers around Chichester [on the south coast] due to the application of roller-stamped patterns on the tiles. Only a few whole voussoirs have been preserved, but a study of these along with the excavated bath plans show that the vaults were generally small [three to five m.]. Later examples of the voussoirs were made with thinner walls, and their use in large-spanned [nine to 13 m.] unheated rooms demonstrates that the hollow voussoirs were subsequently adapted into a structural device to reduce the lateral thrust of very large vaults, such as those at the Sanctuary of Sulla Minerva at Bath.

Rainer Atzbach

Aarhus University, Denmark

The Stube: Constructive Evidence for the Concept of a Smoke-Free Heated Living Room between the Alps and Southern Scandinavia

Based on archaeological evidence as well as written and pictorial sources, the project explores the spread of the tile stove and of a specific floor plan connected to it. In the North Alpine area, the tile stove was invented in the eighth century. Apart from convection air heating, this system provided the only possibility of a smoke free heated living room. The use of the tile stove spread towards the north and reached the southern Scandinavian region by the 12th century. In the Upper German speaking area, the tile stove was used from the 13th century in a characteristic floor plan, which consisted of the stube, adjacent kitchen, a central corridor and unheated chambers in three bays and two or three aisles, the so-called nine-fold floor plan. In contrast to the spread of the heating system, this floor plan only gradually was adapted in the Lower Mountain Range, northern Germany and southern Scandinavia by the 16th century.

Spyridon Papavasileiou, Magdalini Makrodimitri, James Campbell

University of Cambridge, UK

The Construction and Integration of Historic Heating Systems in Churches in the United Kingdom from the 17th to the Early 20th Century

The study of historic environmental systems in the UK prior to the introduction of air-conditioning in the 20th c. reveals outstanding innovations in the development of heating-systems and their adaptation to architecture. This paper attempts to clarify the range and history of construction, appendage and assembly of heating systems, from the 17th - early 20th century in the UK, using the church building type. The heating of churches remains largely unexamined in construction history, although it is rife with examples of profound ingenuity and innovation. A literature review has been undertaken, examining both primary and secondary sources but also historic systems still found intact. A revised classification re-assesses the localised and central heating categories by examining each system's components, assembly and function. Conclusions highlight the importance for further research on the origins, effects and history of these developments.

Carlo Manfredi

Politecnico di Milano, Italy

Comfort versus Industry: Maintenance of the Royal Palaces of Milan during the 1860s

Despite the fast and widespread distribution of technical literature, technical knowledge is assimilated very slowly and in varying ways. This study is based principally on documents found in the State Archives of Milan and shows exact dates and phases of the building work developed and carried out on the Building Sites of Court Buildings and the royal palaces of Milan. In the mid-19th century, technology for buildings, heating, dwellings, factories and conservatories were well understood throughout Europe. Experimentation was focused on official buildings such as seats of political power, churches, hospitals, theatres, Lariboisière Hospital and the Palace of Westminster. An enormous number of buildings, e.g. those belonging to the Habsburgs, the Papal States and the southern Kingdom of Two Sicilies, founded by the House of Savoy after the unification of Italy, needed maintenance and renovation. A widespread program of maintenance work began and local supervisors were put in charge of the building sites.

Sessions

Friday 6 July, 15:00-16:30 VERSAILLES SITE

- 302. Construction History, Sources & Methods 1
- 305. Rules & Standards, Architectural and Urban Norms
- 308. Training & Education 1, Engineers
- 309. Technical Literature, Manuscripts
- 311. Craftsmanship & Technical Tasks
- 315. Metal
- 320. Prefabrication 2

302. Construction History, Sources & Methods 1

Chair: **Hentie Louw**, SAPL Newcastle University, UK,

Pierre Guibert et al.

Centre de Recherche en Physique Appliquée à l'archéologie, CNRS-Université de Bordeaux 3, France

The Use of Dating Methods for Studying Building Materials and Constructions: State of the Art and Current Challenges

The results of research conducted by the CNRS European research group “Ceramic Building Materials and New Dating Methods” are presented. We focused our studies on a series of monuments constructed before 1000 A.D. in France and south-east England. They include ceramic elements such as bricks or tiles. These constructions are well known by archaeologists of the medieval periods, historians and art historians, but they were dated, in most cases, either by textual sources or by typology. Luminescence techniques [thermoluminescence and optically stimulated luminescence] and archaeomagnetism were employed to date brick production, in conjunction, with radiocarbon dating of charcoals found in mortars. Different practices were identified: reuse of materials, production of bricks *ad novo*, and association of reused and new ceramic elements in the same masonry. Dating bricks produced *ad novo* allowed us to refine or revise the building chronology. Dating mortar by OSL, as a direct access to information about construction is one of the challenges posed to the dating community.

Rita Vecchiattini

Department of Sciences for Architecture, University of Genoa/ Institute of the History of Material Culture [ISCUM], Genoa, Italy

Giovanni L.A. Pesce

Department of Architecture and Civil Engineering, University of Bath, UK / Institute of the History of Material Culture [ISCUM], Genoa, Italy

A Study on the Traditional Production of Lime: The Role of Oral Sources

Lime is one of the most common building materials. It has been used since the sixth century before Christ but it was almost completely abandoned between the 19th and 20th century in favor of a new binder with higher mechanical properties and a very short setting time: cement. Because of this, old knowledge [“art secrets”] on production and the use of lime was increasingly reduced in the past two centuries and, currently, few people still possess knowledge on traditional lime production. This paper describes how these

people [oral sources] are able to supply useful information on old lime technology. This information is useful in many research fields such as history and archaeology but also in the material science for the development of new construction materials.

Mariachiara Faliva

Thornton Tomasetti, Inc., New York City, NY, USA

Integrated Methods for the Study of Construction Techniques

The purpose of the paper is to present how high technological methods and more traditional research tools can be successfully integrated in the study of construction techniques and how each approach contributes to the final result. Some case studies, taken from the research done in 2006 on the Sacro Monte di Ossuccio, a complex included in the UNESCO World Heritage List, will be presented to illustrate the application of methods such as topographic survey, Infrared Thermography, stratigraphy, field measurements, archival research and use of past construction manuals. The first case study will illustrate the analysis of an early 18th century stone and earth promenade. The second case study will show how active Infrared Thermography combined with the consultation of 19th century construction manuals revealed construction techniques used for the erection of the dome of one of the chapels in the complex.

305. Rules & Standards, Architectural and Urban Norms

Chair: **Robert Carvais**, CNRS-Université Panthéon-Assas / ENSA de Versailles, France,

Juliette Hernu-Bélaud

University of Nantes / Institut national d'histoire de l'art, Paris, France

The Architecture pratique by Pierre Bullet [1691] and the Normalisation of the Construction Process

Architecture pratique was published by Pierre Bullet in 1691. This practical book proposed a complete method of measurement, as well as a model estimate. The aim of this paper is to show how this treatise can be considered as an expression of a particular vision of the architectural profession. How did the architect contribute to normalisation of the practices? How did he minimise the variable aspects of construction? How did this lead to the strengthening of the quantitative aspect of the architectural project?

Esperanza González Redondo

Alcalá University, Madrid, Spain

The Structure of Houses in Madrid 1669-1900: Buildings and Documents

Several timber frame houses built in the historical centre of Madrid since the 18th century have been preserved. Structural decay in these buildings is very common, mainly because of poor conservation and, in fact, many houses have been demolished in the last decades. This study, where an analytical approach to documents has been carried out in the Historical Archives of Madrid, follows previous studies. This approach could be divided into three main sections: first, traditional construction methods in Madrid within context. Next, the approach was extended to look for documents about the construction systems used in that time, together with a study of Madrid's bylaws, Madrid's historical plans and Spanish construction treatises. Finally, three groups have been established taking into account information covered in construction contracts and the fact of being able to get information from real buildings.

Silvia Amaral Palazzi Zakia

Faculdade de Arquitetura e Urbanismo de São Paulo [FAU-USP], Brazil

The First Building Code of Campinas – 1934: A Legal Instrument of the Urban Modernization Process of the City

Campinas, a city located 90 km from Sao Paulo—which was, during the second half of the 19th century until the early 20th century, an important economic center of the country responsible for producing most of the coffee exported from Brazil—survived the 1929 crash and subsequent fluctuations in the coffee market by encouraging an industrialization process that would completely alter the physical appearance of the city. A process of urban modernization was initiated by the government between the 1930s and 1950s. Through the initiative of the municipal government, a committee consisting of four engineers was organized with three professionals from the private sector and one from a public power and they were entrusted with drawing up a code of construction, the first of the city. The article focuses on the development of the new code that established rules and building norms in accordance with modern pre-requisites.

308. Training & Education 1, Engineers

Chair: **Guy Lambert**, ENSA Paris-Belleville / HTTP-CNAM, France

Willemijne Linssen, Krista De Jonge

University of Leuven, Belgium

How Belgian Engineers Passed on Their Knowledge between 1830 and 1865: Education, Association and Publication

Between 1830 and 1865, engineers who were initially identified as state officials increasingly conquered the industrial private sector. Considering the case of Belgium in this period of transition, we will look at three specific tracks of knowledge transfer. In chronological order these are: educational institutes, professional associations and publishing journals. The first associations were indeed societies of alumni closely connected with particular engineering schools organised by the State and by other actors. Alumni journals constitute an important information source for the study of nineteenth-century engineers and engineering. For context, these journals will be compared to the *Bulletin du Musée de l'Industrie*, which developed a broader scope.

Mike Chrimes

Institution of Civil Engineers, London, UK

Short of Education or Short of Engineers: British Civil Engineering 1890-1910

Since the development of civil engineering as a profession in the late 18th century, the British practice-based approach to the formation of civil engineers has been regularly contrasted with the continental European, more academic approach. Many have alleged that the British approach contributed to slower economic growth in that country and less innovation. At the end of the 19th century, the Institution of Civil Engineers seemed to accept some of this criticism as it introduced examinations for the first time. However there were other influences at work, and one alternative argument might be that it was the numbers of engineers, rather than their education, that held back developments in structural engineering and economic growth among the civil engineering profession in Britain.

Simona Talenti

University of Salerno, Italy

The Italian Engineers' Architecture and Technique Training

This paper aims to analyze the role and the importance accorded to architecture in the training of Italian engineers between the 19th and 20th century. Careful examination of teaching programs that professors – like Calderini, Muggia etc. – offered to young students, will emphasize the interest in the discipline of architecture and its history. The chair of Technical Architecture in the Application Schools for Engineers and later in the Faculties of Engineering, testified to this attitude. It was, in effect, a teaching that was both technical and artistic. The teaching of the engineer Guerra in Naples [1920-1960] confirms this interest in architecture and in particular in the examples of the past. Constructive elements and technical aspects are often related to the history of architecture and to the practice of drawing. The paper aims to focus on the Italian teaching and pedagogy with particular emphasis on the period from the late 19th to mid 20th centuries.

309. Technical Literature, Manuscripts

Chair: **Joël Sakarovitch**, GSA-ENSA Paris-Malaquais, France

Paola Travaglio

Politecnico di Milano, Italy

“De Fenestris”: An Unpublished Treatise from the Mid 15th Century on the Construction of Windows and Stained Glass

The ms. Canonici Misc. 128 of the Oxford Bodleian Library preserves an unpublished treatise concerning the creation of windows and stained glass, entitled *De fenestris*, as part of a larger work called *Thesaurus pauperum*, an opera composed during the first half of the 15th century in the Veneto region, comprised of 15 brief texts regarding various artistic and artisan activities. Arranged in 21 recipes, the *De fenestris* addresses the production of various types of glass, describing the procedures of coloration in enamel and cold painting, production of pot-metal glass, the refiring of painted glass, construction of windows utilising animal hides and paper, glass cutting and the production and soldering of metallic bands used to connect the panes. This contribution, in its presentation of the original treatise, is intended to offer an integral transcription, including philological-literary analyses and technical commentary and to present a synthetic comparison with other Medieval texts dedicated to the production of stained glass.

Francesco Menchetti, Laura S. Pelisetti

Faculty of Science and Architecture, Polytechnic of Milan, Italy

Guidobaldo del Monte as Architect and the Construction of Santa Maria degli Angeli in Pesaro

Guidobaldo del Monte combines his experience as scientist, to a copious activity as an architect in the service of Francesco Maria II, Duke of Urbino, proving to be “pratico [...] di Architettura et edifitij.” The quotation by Girolamo Ardizi is supported by the words of Guidobaldo himself, reported in the depositions of the lawsuit filed in 1589 by the Camaldolese fathers for the collapse of the roof of the church of Santa Maria degli Angeli. The architect makes several assumptions to overcome the disastrous collapse and describes in particular an original vault [*in folio*] with an extraordinary round. It is certainly not a theoretical treatise but a pragmatic approach to questions related to the strength of materials, a theme never before presented in studies on Del Monte. Galileo, a correspondent for Guidobaldo, introduces his authoritative study on the resistance of materials, citing cases of recurring failures in Renaissance engineering.

Marisa Tabarrini

Sapienza Università di Roma, Rome, Italy

An Unpublished Treatise on Waters by Vincenzo Della Greca: A Source of Carlo Fontana's Utilissimo Trattato Delle Acque Correnti

The modern return of the water in Rome is due to the determination of two Popes Sixtus V [1585-1590] and Paul V [1605-1621]. For the management and control of new water resources, they created appropriate institutional bodies entrusted to administrators and architects with special hydraulic knowledge. The water became one of the major themes of scientific investigation with a deep impact on the production of treatises, manuals and literature. Most important of them all is a treatise by Benedetto Castelli, *Della misura dell'acque correnti* [1628], which contains scientific principles largely exploited in the later writings on hydraulics combining science and practice mainly directed to specialists in construction and urban development. Completely unknown to scholars is the unpublished treatise *Delli effetti delle acque di Vincenzo Della Greca Architetto civile, et militare della Regia Camera Apostolica* [1642], which anticipates in contents and illustrations the work of C. Fontana, *L'Utilissimo trattato delle Acque Correnti* [1692].

Friday 6 July, 15:00-16:30 VERSAILLES SITE, Room E251

311. Craftsmanship & Technical Tasks

Chair: Valérie Nègre, ENSA Paris-La Villette / HTTP-CNAM, France

Silke Kapp, Ana Paula Baltazar

Universidade Federal de Minas Gerais, Belo Horizonte, Brazil
Metropolitan Vernacular: On the History of Informal Construction in a Brazilian City

The expression 'metropolitan vernacular' stands for the contradictory synthesis of formal construction technologies and informal popular building practices, which characterises self-produced urban areas in developing-countries. Just like any vernacular, the 'metropolitan' is based on learning-by-doing, imitation and resources at hand, but its models and resources are found in an urban context, dominated by a highly profitable construction industry, which was always conceived against vernacular and even against traditional craftsmanship. The result is a bricolage from fragments of industrialised materials and techno-scientific knowledge. This paper describes a possible construction of the social and material history of this self-production of everyday spaces, based on documental sources, broader interpretations of sociospatial processes, participant observation, and an ongoing collective project with residents of the favela Vila das Antenas. The aim of this history is to make its protagonists aware of the value of their own production of space.

Gülşah Çelik

Faculty of Architecture, Middle East Technical University, Ankara, Turkey

Kemal Reha Kavas

Department of Architecture, Akdeniz University, Antalya, Turkey
A Case Study of Local Builders' Carpentry Tools: Traditional Constructions of Ürünlü, Turkey

This study explores the traditional construction tools used in Ürünlü, a rural settlement in southwestern Turkey. The architecture of Ürünlü is characterized by masonry incorporating timber and rubble stone. Carpentry plays a key role here because the structural system and the interior spaces require craftsmanship. While surviving dwellings constitute the material sources of research in construction history, oral sources inform about the construction processes and tools. It is known that constructions were undertaken by specialized designers and builders. These professionals were trained through the handing down of architectural traditions. In this framework this study focuses on the hand tools of İhsan Özen, a local carpenter. These tools were used for shaping

rough pieces of timber used for producing doors, windows and cupboards. This analysis unfolds one of the specialized professions shaping Ürünlü under specific cultural and economic circumstances.

Elizabeth Cook

College of William and Mary, Williamsburg, VA, USA
Building Culture and Competence: Demonstrating Knowledge on Construction Sites in 18th Century Virginia

To succeed both personally and professionally in 18th century Virginia, carpenters had to demonstrate "competence": a mastery of their craft that allowed the carpenter to secure his economic independence through the practice of his trade. To do so meant demonstrating skills equal to or surpassing those of other carpenters working in the area, often while the two were sharing a job site. This paper examines two sites on which Williamsburg carpenters plied their trade in an attempt to understand how these men related to one another as members of a shared professional community and how they differentiated themselves within the local labor markets. It views both the work site and the work undertaken as elements of performance, knowledge, and craft mastery.

Friday 6 July, 15:00-16:30 VERSAILLES SITE, Room E217

315. Metal

Chair: Karl-Eugen Kurrer, Ernst & Sohn, Germany

Maxime L'Héritier

Institut de Recherche sur les Archéomatériaux-CNRS UMR 5060
Centre Ernest Babelon, Orléans, France

Philippe Dillmann

LAPA IRAMAT CNRS, France

Arnaud Timbert

Université Lille 3-CNRS, France

Philippe Bernardi

Université Paris 1-CNRS-LAMOP, France
The Role of Iron Armatures in Gothic Constructions: Reinforcement, Consolidation or Commissioner's Choice

Over the past ten years, several studies have shown that iron was included in the design of most gothic monuments. However, beyond quantitative aspects which mainly regard the building yard's supply, all these iron armatures, from the simple cramp to the structural chain, cover different architectural conceptions, depending on the building and its chronology, which have to be considered. This paper proposes to consider every single structural use of iron in gothic buildings from the 12th to the 16th centuries regarding recent research on historical sources as well as on the buildings themselves, to give a classification and initiate inquiries about the apprehension of iron use by medieval master-builders.

Guillaume Fonkenell

Musée du Louvre, Paris, France
The Roof Frame of the Salon Carré

The restoration of the roof of the Salon carré in the Louvre, undertaken in April 2010 was an opportunity for a detailed examination of the 1789 metal frame. Designed by the architects Charles Axel Guillaumot and Jean-Augustin Renard, it is one of the oldest wide span metal structures still extant on site in France, and is made of wrought iron members filled with hollow terracotta dwarf studs held together with plaster. Thus, under the traditional shape of a curb roof the structure is highly innovative and allows the creation of a wide skylight at the top of the roof. The choice of iron was also justified by economic considerations and by the desire for a "non combustible" structure. The frame of the Salon carré was presented as the adequate answer to the various problems of a museum, a place to exhibit in good conditions and to preserve works of art.

Paul Dobraszcyk

University of Manchester, UK
A Victorian Ironworld: Cast Iron, Ornament and Brighton

This paper explores the design and perception of cast iron in Victorian seaside architecture, concentrating on Brighton, the largest British resort throughout the 19th century. It focuses on two distinct but interrelated themes: first, the role of cast iron in creating Brighton's seaside environment and, second, the visual language of iron in its seaside architecture. I structure the paper around analysis of the constituent elements of iron seaside structures, from the smallest – balconies – to the largest, namely piers, shelters and covered promenades. Above all, this is a story of gradual development in the scope of ambition in relation to cast iron and seaside architecture, moving from a relatively modest application of the material in the first half of the 19th century to an all-encompassing approach by the century's end. Throughout the paper, I will consider the visual language of cast iron in Brighton, which has generally been labeled under the blanket term "orientalism" which has, at best, resulted in a superficial treatment of the subject. My concern will be to tease out the specifics behind this generalised categorisation and I set about this primarily through analysing a more local orientalism – that is, that which developed in Brighton's iron structures. The result will be to situate Brighton's seaside orientalism in the wider context of what Stephen Ward terms "place selling," that is, the projected image and "social tone" of the resort in a landscape of often intense local and/or national competition.

Friday 6 July, 15:00-16:30 VERSAILLES SITE, Room E223

320. Prefabrication 2

Chair: **Hernando Vargas**, Universidad de los Andes, Colombia

Yvan Delemontey

Ecole Polytechnique Fédérale de Lausanne, ENAC - IA-TSAM, Switzerland

Flaine: Mountain City; The Building of a High Altitude Citadel

The fruit of an exceptional collaboration between an enlightened client [Eric Boissonnas] and an internationally renowned architect [Marcel Breuer], Flaine [1959-1988] is a unique example of the winter sports resort genre. At 1600 m., on a mountainside facing Mont-Blanc, it is emblematic of the triumph of modernity in the France of the 1960s. Known for the excellence of its ski slopes, Flaine has been disparaged for the *béton brut* of its architecture, which echoes the major housing projects built around the country during the same period. The connection is entirely pertinent, since the ski station was built using the same heavy prefabrication methods used in the building of mass housing. An atypical choice in the history of the winter sports facility, the technique simplified site and project organisation on a scheme of such varied technical achievement and enabled huge façade panels in relief to be developed, which quickly became a Breuer trademark.

Maite Palomares Figueres, Jéscica Moreno Puchalt, Veronica Llopis Pulido

Polytechnic University of Valencia, Spain

Architectural Expression in the 60s and the Prefabrication of Formwork

In the 1960s, the technology of reinforced concrete provided highly expressive architectural solutions linked mainly to laminated structures. However, although less common, we can also cite several particular cases of framework structures where the expressiveness stems from both the material chosen and the ingenious design of the structural solution. This is so in the case of Santa María del Mar church in Jávea [Spain], built in 1963 and undertaken by the GO.DB. Arquitectos, with the roofing being reminiscent of Le Corbusier's Notre Dame du Haut chapel.

Formworks moulded the shape and lent expressiveness to the new material, a detailed study of their geometries and individual pieces being required, which involved a painstakingly precise constructional system. In Jávea, moreover, the formwork system required a particular

prefabrication. The large formwork pieces, shaped with three-dimensional curved boards and the positioning of the reinforcement for the enclosing pillars were made entirely in a workshop and were then erected on site.

Sonja Hnilica, Markus Jager

TU Dortmund, Germany

Competing Building Systems: Post-War University Architecture in the Ruhr Area

Today, three universities exist in the Ruhr area with about 90,000 enrolled students and all were founded and built between 1960 and 1985. Designed as universities having undergone reformation, manifesting equal opportunities to study for all young people, extraordinary efforts were necessary to implement an ambitious building program. An enormous construction volume, planned in a very short span of time, was built at considerably low costs. The university buildings in Bochum, Dortmund, Duisburg and Essen are perfect examples for retracing the rise and fall of building systems types. Whereas in Bochum an international competition resulted in building a monumental prefabricated megastructure, other universities had to be content with a much more modest architecture. Different building systems were tested, culminating in the development of the building system titled "NRW 75." This system was used for planning and building the TU Dortmund and The University of Essen. In the End, the newly developed system was discontinued in Duisburg before it was completed.

Sessions

Friday 6 July, 16:50-18:20 VERSAILLES SITE

301. Construction History, Sources & Methods 2

307. Training & Education 2, Architects

312. Labor Market

313. Ownership of Property

318. Interior Environment, Lighting

319. Saving & Recovery Energy

322. Infrastructure & Public Works

Keynote Lecture

Friday 6 July, 18:40-19:40 VERSAILLES SITE [AMPHI LA FORGE]

Robin Middleton

Department of Art History and Archaeology, Columbia University, New York City, NY, USA

Jean Rondelet's Pioneering Attempt to Write a History of Construction, 1801-02

From Vitruvius on, architectural treatises have included something of the history of construction, but the first history of construction as such seems to be an essay [92 pages] submitted by Jean Rondelet in a competition promoted by the Institut national des sciences et des arts in 1799. He was awarded the prize three years later, but the essay was not to be published. It is not, in fact, altogether satisfactory as a founding history of construction. There are tediums. Rondelet deals with his history as a sequence of accounts of building techniques: timber construction, with much on the pitch of roofs; stone construction, the emphasis here on the moving of large blocks of stone; mortars, with the emphasis on Roman walling; sun-baked bricks,

with an aside on pisé; then fired bricks; leading to a discussion of domes in Ravenna and Venice; on to Gothic construction, and thus to some remarks on stereotomy [which he considered exhibitionist]. Other than a list of names, there is nothing on the major advances in the calculation of structures made in the preceding hundred years, nothing on the revolution in bridge building in France in the eighteenth century, or even on the iron-reinforcement of buildings, with which Rondelet was himself so deeply involved. His omissions are, indeed, more interesting than the subjects he covers, and, for that reason, are sketched in to provide a proper context for a consideration of his performance.

301. Construction History, Sources & Methods 2

Chair: João Mascarenhas-Mateus, CES-University of Coimbra, Portugal

Amparo Graciani

University of Seville, Spain

Mesopotamian Foundation Deposits in the Louvre Museum

The Louvre Museum possesses an interesting set of foundation deposits of various types and spanning a number of periods, most of which are housed within two departments of the Museum, especially in the Department of Oriental Antiquities [Oriental Antiquités]. These foundation deposits from the Department of Oriental Antiquities relate principally to Mesopotamia and Persia, upon which this paper is also focused. Specimens currently on display in these rooms are analysed, by means of a tour of the following five circuits: 1) The first foundation documents: the archaic and early Dynastic period [Room 1]; 2) The art of the foundation documents at the time of Gudea of Lagash, Second dynasty [Room 2]; 3) The continuity of the second millennium B.C. [Room 3]; 4) Assyrian contributions to Mesopotamian tradition [Room 4], and 5) The Mesopotamian influence on the Iranian area [Rooms 8, 9 and 10].

Dirk Bühler

Deutsches Museum, Munich, Germany

The Collection of the Deutsches Museum: A Source for Research on the History of Construction

Museums and their collections can represent an inestimable source for research on construction history. One of the most comprehensive collections of objects and documents dealing with construction techniques and their history is registered with the Deutsches Museum [Munich, Germany]. Ever since it was founded in 1903, the museum has been collecting objects related to construction technology in general and their applications in civil engineering and architecture [currently 2,613]. The main construction materials, their production and use are illustrated by the necessary testing devices, production methods, possible applications, surface treatment and final implementation in buildings. This paper focuses on the objects, models, dioramas and paintings in the collection of the Deutsches Museum that relate the development of the cement and concrete industry and technology and interprets it in the context of the history of construction.

Carolina Heldt D’Almeida

Instituto de Arquitetura e Urbanismo da Universidade de São Paulo [IAU-USP], São Carlos, Brazil

Analysis of the Construction Site as a Historical Document of Its Production Process

The object of study of this paper is the construction work of Ilha Solteira Hydroelectric Plant, built in Brazil between 1965-1974. This paper seeks to analyse the construction site as a historical document. The goal is to examine the process of production and work in construction as a field of reflection of ways to rationalise work in the “construction site form of production” of a large-scale construction. To this end, the rationalisation of work at Ilha Solteira was analysed examining each work site and the general production flow. It was found that in Ilha Solteira the form of production combines different stages of division of labour, which indicates how the contradiction between “backward” and “modern” aspects, present in the modernisation of the construction at that time, would have been reconfigured in a form combining and accommodating them, blurring the perspective of overcoming the precarisation of work at the construction site.

307. Training & Education 2, Architects

Chair: Robin Middleton, Columbia University, USA

Hélène Rousteau-Chambon

Université de Nantes, France

Teaching Construction in the Académie Royale d’Architecture

In 1698-1699, 1705-1706 and 1714-1715, Philippe de La Hire gave lessons on architecture [*Traité d’architecture*] in which he discussed and analyzed all the elements and steps of the construction process. For example, he studied materials and devoted himself to the different parts of structures such as bridges or an atypical and specific theme of construction: the way to rebuild underwork. In fact, while he had a really practical conception of architecture he attempted, at the same time, to follow an old theoretical approach [Vitruvius, Palladio] and he is the first French theoretician to pay so much attention to those subjects. Outside the academy, La Hire’s lessons on construction had a real posterity: La Hire’s plan and sometimes words were picked up in *Architecture moderne* ou *L’art de bien bâtir...* Patte also, in Blondel’s *Cours d’architecture* [1771-1777], retook La Hire’s ideas and added innovations at the same time. But La Hire is the only one who explained hydraulics, bridges and the way to rebuild underwork for example. So, La Hire’s lessons are a very important landmark to understand the most important and famous lessons on construction of the 19th century.

Valérie Nègre

ENSA Paris-La Villette / CNAM- HTTP, Paris, France

Oral Transmission and the Use of Models in the Teaching of Architecture and Construction at the Turn of the 19th Century

The use of models in lectures on architecture isn't very well known. But like drawings and images, models were used to mediate between verbal description and reality. As these disappeared, so too did a representation of materials that complemented oral communication, which photographs or slides did not replace. Subsequently, with the growing importance of lectures and due to their very nature, the teaching of architecture in French schools inexorably turned towards abstraction. This paper will address the question by examining what types of objects were used in teaching architecture and construction at the turn of the 19th century, how these were handled and the reasons that led to using them.

Guy Lambert

ENS Architecture Paris-Belleville / HTTP-CNAM Paris, France

“Purpose” and “Means” of Architectural Design: Construction in Julien Guadet’s Teachings in Architectural Theory

This paper aims at examining the importance taken by construction’s principles in *Éléments et théorie de l’architecture* [1901-1904] a textbook based on Julien Guadet’s teaching at the École des Beaux-Arts of Paris. It is closely related to the way in which Guadet considers a course in theory for pupils/architects, which had to stick to “the uncontested.” In the filiation of the course taught by Léonce Reynaud, while teaching the elements of architecture, he gave special attention to construction. The biased system of the Ecole, where architectural competitions generated a “worship of hugeness” among the students, engaged Guadet to focus on what was “constructible.” In addition to his will to transmit the rules of ordinary construction, he wanted to show that the logics of construction, legitimized by practical considerations such as economy and durability, should rule over architectural design.

312. Labor Market

Chair: **Claes Caldenby**, Chalmers University of Technology, Sweden

Linda Clarke, Charlie McGuire, Christine Wall

University of Westminster, London, UK

The Significance of Building Labour to the Production of the Built Environment

The paper identifies key characteristics of the development of building labour in Britain at different historical stages, pointing also to the sharp disparities between a socially regulated and unregulated wage, collective versus individualised employment relations, and comprehensive versus trade-based training. It focuses on the post Second World War period, showing how within each stage different labour processes co-exist. This is evident in the final product, as shown in the building of key construction projects – including the Barbican, Stevenage New Town and Sizewell. What stands out is the continued trade-based character of the construction labour process in Britain, conceptualised in relation to a range of tasks in the workplace and to work as a specific output of labour rather than the capabilities or qualifications of the person. The paper draws on a literature review and documentary archives, as well as interviews with building workers engaged on these projects.

Jörn Janssen

European Institute for Construction Labour Research, London, UK

Ernst-Ludwig Laux

Industriegewerkschaft Bauen-Agrar-Umwelt, Mühltal, Germany

Construction Work in Four German States: Before, during and after the Cold War

This paper focuses on labour relations in construction as the dynamic force of historical change. After the collapse of both the socialist and capitalist systems, the present economic crisis and political uprisings have alerted us to rethink our categories of analysis. In the industrialised countries of the 20th century, labour relations were divided between Capitalism and Socialism. After World War II, this division took the form of the iron curtain between these camps of the Cold War. For the span of 40 years, this curtain split Germany and its capital into two separate states. Nowhere can the two modes of production under socialist and capitalist regimes be better compared than in this country, and construction provides visual testimony of this crucial period of history. In hindsight, we observe not only the contrast between these contradictory modes but also what they contributed to the common global development.

Christine Wall, Linda Clarke, Charlie McGuire

Centre for the Study of the Production of the Built Environment [ProBE], University of Westminster, London, UK

Concrete Constructors: Oral History Accounts of Building Work on a Large, Complex Site in 1960s Britain

Oral testimonies of former Barbican construction workers are here contextualized against the historic conditions of the building industry, the rise of large complex sites and a crisis in the provision of training. At a time of rapid technical change there was no formal training for concrete work and the concrete workers, steel fixers and shuttering carpenters charged with constructing the complex shapes of these buildings were classified as ‘unskilled’ or ‘semi-skilled.’ The testimonies of these workers reveal the high levels of skill used, that many were already trained in existing building occupations and that, unlike traditional building, the skill entailed in this work was unrecognized.

313. Ownership of Property

Chair: **Jean-Louis Halpérin**, Ecole Normale Supérieure, France

Musa Sroor

Department of History, Birzeit University, Palestine

The Role of the Islamic Pious Foundations [Waqf] in Building the Old City of Jerusalem during the Islamic Periods [637-1917]

The large number of Islamic *waqf* in Jerusalem provided permanent sources of funding through the construction of shops, markets, baths and caravanserais in Jerusalem or through the reconstruction of existing buildings belonging to *waqf*. This explains the proliferation of hundreds of commercial *waqf* properties in the various markets and quarters of Jerusalem. This research proposes that establishments supported by *waqf* and their affiliated real estate played a crucial role in the building of Jerusalem and developing its architecture. Through knowing the dates when the *waqf* buildings were constructed, one can identify the periods of building in Jerusalem and the architectural development of the city. This research paper will rely on judicial documents such as those from the court records [sijill] of the Islamic Ottoman court of Jerusalem [mahkama shar’iyya] as well as from the Jerusalem *waqf* archive.

Clara Pimenta Do Vale

Centre for Architecture and Urbanism, Faculty of Architecture, University of Porto, Portugal

Vítor Trindade Abrantes

Faculty of Engineering, University of Porto, Portugal

Urban Dynamics and Horizontal Property: Case Study of the Boavista Axis, Porto, Portugal

The horizontal property regime was established very late in Portugal [1955], but had important repercussions upon subsequent real estate developments. In fact, the urban land register itself developed as a result of the need to individualise ownership in accordance with the site on which the property stood. The law also had important implications for urban design. The aim of this paper is to analyse the urbanization and building mechanisms that developed in the wake of this specific legal provision; for, although the new law did not directly regulate building activity, it nevertheless had important repercussions upon construction dynamics in the city of Porto. The analysis is based on a particular case study, the axis of Boavista in Porto, an urban alignment around seven km long that drove the city’s westward expansion during the 19th and 20th centuries.

Miguel Artola Blanco

Universidad Autónoma de Madrid, Spain

Changing Patterns in Residential Construction and the Real Estate Market: Spain, 1910-1960

Since the First World War, the construction and the real estate market in European countries experienced a significant transformation. In Spain, the growing criticism towards private landlords was a key factor for the approval of new policies that sought to protect tenants through rent regulation and the extension of leases. In the medium and long-term, these policies imposed an erosion of rents, therefore reducing rental residential investment.

Along with this process, since the 1940s, Franco’s regime designed a new construction model that has subsisted until today. The two most salient features of this new model were the promotion of home ownership and an increasing participation of public authorities in the financing of residential investment. Finally, we discuss the consequences of this model on the economic and social development of Spain, comparing differences and similarities with other European countries.

318. Interior Environment, Lighting

Chair: **Nathalie Simonnot**, LéaV-ENSA de Versailles, France

Laura Balboni, Paolo Corradini, Angelo Landi

Politecnico di Milano, Italy

Artificial Light in the Aristocratic Palaces in the Po Valley between the 17th and 18th Centuries

The research is focused on a careful analysis of several aristocratic palaces in northern Italy between the 16th century and the first half of the 17th century; in this period a great increase in the use of artificial light in the state apartments was found. The architectural projects began to involve the effects of the artificial light in the inner halls; in this respect, decorations, the technological details of the lighting devices, the structures supporting the chandeliers and the systems of ventilation are reinterpreted. Sometimes, in order to fix more lighting devices in the halls, the architectonic structures were adapted with projecting balconies or platforms for the orchestra. The comparison between the analysis of the documents and the examination of the material traces allow the reconstruction of the process of gradual development in the night life in aristocratic buildings.

Giulio Sampaoli

Accademia di Architettura, Mendrisio, Switzerland

Artificial Light in Architecture in France and Italy during the First Years of the 20th Century: From Gas Light to Electric Light

Architects have always been attentive to the use of natural light in design, but rarely to the qualities that artificial light can confer on a work of architecture. Only in the late 19th century, slowly but progressively, did artificial lighting, first provided by gas and then electricity, pass from being a luxury for the few to a utility available to everyone and necessarily altering architectural development. While gaslight in the 19th century influenced the perception of interior design and released society from dependence on sunlight, after 1870 the development of electricity and the steady spread of electricity for civil uses in Europe led to a true evolution of lighting and then of architecture itself. With electricity providing "clean" illumination, it was possible to vary the distribution of light, so that it gradually became the new 20th century "building material" which, though the intangible, enhances the functionality and appeal of architecture.

Giulia Marino

Ecole Polytechnique Fédérale de Lausanne – EPFL-ENAC – IA-TSAM, Switzerland

The World Health Organization Headquarters in Geneva [1960-1966]: How Mechanical and Electrical Services are Integral to Reading Built Form

The permanent headquarters of the World Health Organization, in Geneva, is recognized as one of the major works of Jean Tschumi, who won the international competition in 1960. Shaped by the imposing linear block housing the Secretariat and the Conference Hall at the lower level, the ensemble displays a highly individual plastic expression that profits remarkably from the technical solutions used. From the spectacular pre-stressed concrete frame structure to the conception of the aluminium and glass envelopes animated by a subtle, slanted brise-soleil, the incorporation of some very smart – and decidedly novel – technology assists in the architectural definition of the international body's remarkable European home. As the specialist press at the time was keen to emphasise, the latest technical gadgetry featured prominently in Tschumi's design. The technology assumes a particular interest not only because of its complexity, but also because of the close relations established with constructional elements. This interaction deserves to be explored; this paper will propose a reading of the material aspects of this group of buildings centered on the notion of integrated building engineering systems, a notion of major importance that is all too often overlooked.

319. Saving & Recovery Energy

Chair: **Carlo Manfredi**, Politecnico di Milano, Italy

Kambiz Mosthtaghe Gohari

GSA-ENSA Paris-Malaquais, France

The Morphological Evolution of the Vertical Axle Windmill between the Second and the 18th Centuries A.D.

In contrast to the watermill, the windmill was unknown in the Roman Empire; the first windmill was created around the second century A.D. in Iran [Persia]. The architectural elements in the morphology of the vertical axle windmill have various functions. The evolution of the building techniques used in different types of windmills led to the birth of the best and the most functional morphology in service of the technical mechanism. In this article, three major axes of inquiry will be followed: the historical documents and the scholarly literature by authors in the discipline, the morphological evolution of the vertical windmill and the role of architectural elements in the technical mechanism. A chronology of the different kinds of windmills in the Middle East will also be presented. It will show us the various morphogenesis patterns of the vertical axle windmill in Iran.

Daniel A. Barber

Barnard College / Columbia University, New York City, NY, USA

Constructing a Solar House, c. 1959

This essay explores the solar house design competition "Living With the Sun," sponsored by the Association for Applied Solar Energy and held over 1958-1959. The logistics of the competition are briefly detailed, followed by an extended analysis of the 60 published competition entries. These 60 entries are seen to not only indicate the interest in solar housing in the period, but also to serve as an important catalogue of modern architectural strategies in post-war America. The winning house is then described at some length, with special attention to the challenges of constructing a solar house in the 1950s. Issues of materials, concerns over how to encourage innovation with contractors and in the building industry, and the design of the solar system are all discussed. Finally, the sad fate of the house, its mechanical solar heating system largely unusable, is placed in the context of other techno-cultural endeavors of the period.

Samaher Wannous

HTTP-CNAM, Paris, France

The Thermal Insulation of Facades after the Oil Crisis of 1974 to the 80s

This paper shows the relationship between architectural and technical research dedicated to the reduction of energy consumption in construction after the oil crisis of 1974 in France. As a consequence of the rise of oil prices in the early 70s, the necessity of saving energy in construction appeared. The term "hunting for waste" and the first thermal regulations in France were created. Consequently, the insulation of attics and walls and the promotion of double-glazing in new construction were introduced. The rehabilitation of existing buildings was also encouraged. In this article, we are going to talk about the birth of external insulation. Next, we will evoke the French case and the role of experimental operations in the development of thermal building insulation. Then, we will create a definition of the early types of external thermal insulation that existed in France in the 1970s and the 1980s.

Friday 6 July, 16:50-18:20 VERSAILLES SITE, Room E223

322. Infrastructure & Public Works

Chair: Matteo Porrino, ENSA de Strasbourg / GSA-ENSA Paris Malaquais, France

Carla Maria Amici

Università del Salento, Lecce, Italy

A Cloaca Maxima in the Roman Town of Privernum, Lazio, Italy: The Project, the Plan, the Construction

The recent excavation of a Roman republican town, Privernum, 90 km south of Rome, Italy, has allowed the discovery and the investigation of a channel more than four m. wide, with vaulted roofing, preserved for about 200 m. This waterway, surely the result of straightening a former stream, represents the main sewer of the Roman settlement, dating back to the middle republican period; the intention is to excavate and restore it so that it can be used to drain the archaeological area. The intervention, still in progress, has made possible an accurate examination of the building technique and construction process of the channel. It reveals a design integrated directly into the central part of the town; the need to fix exactly the relation between the channel and the urban planning, which was clearly affected by the layout and the orientation of the conduit, suggests the existence of a master plan.

Rosana Muñoz

Federal University of Bahia, Salvador, Brazil

The Most Important Construction in Bahia's 19th Century History: Salvador's Mountain Retaining Wall

The City of Salvador was founded in the 16th century on the high cliff escarpment of a geographic fault. Although this topography provided an ideal position to defend its urban perimeter against occasional enemies arriving via the Todos os Santos Bay, it also served to create a disaster zone, due to its subsequent landslides. In the 19th century, this cliff escarpment was called the Mountain and it divides the city into two parts: the Upper City and the Lower City. It was not until the mid-19th century that the government began to deal with this potential threat through the construction of a gravity retaining wall, known as the Mountain Retaining Wall. Today this remains the most important structure ever designed to stabilize the city slopes. The aim of this study is to describe the history of this construction, addressing its plans, materials, techniques and related difficulties.

Davide Del Curto, Francesco Carlo Toso

Politecnico di Milano, Italy

Technical Systems and Networks for a Modern High Altitude Settlement: The Construction of the Sanatorium Village in Sondalo [1932-1946]

The Sanatorium Village in Sondalo in the Valtellina valley, Lombardy region, was built by the national institution for social security [I.N.F.P.S.] between 1932 and 1946 on completion of the national scheme for the building of sanatoriums. The autonomous urban and functional program establishes a problematic technical relationship with the alpine and inhabited context in which the complex was built. The paper focuses on the design of distribution networks and technical systems [road system, underground facilities, water supply, sewerage systems] that make the Village a unique achievement among European sanatoriums during the interwar period. Cable cars connected the single pavilions to the main services building, which accommodated the shared facilities and whose parts had to operate simultaneously. The unity of the architectural and technical devices design is nowadays the main reason for the technical difficulties and uncertainty in the redevelopment of the complex, which during the postwar period progressively fell into disuse for anti-tuberculosis care.

Keynote Lecture

Saturday 7 July, 9:00-10:00 MALAQUAIS SITE [AMPHI BINET]

Susan Verdi Webster

Jane Williams Mahoney Professor of Art History and American Studies,

College of William and Mary, Williamsburg, VA, USA

The Secret Lives of Buildings in Colonial Quito: People, Processes and Cultural Optics

This talk is about vision, visibility and cultural optics; it posits that, in many cases, how buildings are perceived within a historical context depends upon who is doing the looking. As a case study, this talk focuses on the people and processes – both Andean and European – involved in architectural production in colonial Quito [Ecuador]. In order to chart the largely unseen construction history of monumental buildings in the colonial city, my approach combines historiographical analyses and

expanded perspectives with extensive documentary evidence from archives and colonial chronicles. Systematic analyses and close readings of these sources substantially revise modern accounts of the authorship, chronology, interpretation, reception, and diffusion of Quito's monumental colonial buildings, and suggest new avenues of approach for understanding architectural production within colonial contexts.

Sessions

Saturday 7 July, 10:30-12:30 MALAQUAIS SITE

409. Structural Analysis & Modeling 3

412. Transfer of Knowledge, Scientific Exchanges

422. Politics & Policies

430. Innovations in Reinforced Concrete

431. Foundations & Masonry

437. Metal Structures 2

439. Interior Environment, Heating, Ventilation & Hygiene

Closing Discussion

Saturday 7 July, 12:30-13:30 MALAQUAIS SITE [AMPHI 2]

409. Structural Analysis & Modeling 3

Chair: **Santiago Huerta**, Universidad Politécnica de Madrid, Spain [TBC]

Paula Fuentes

Universidad Politécnica de Madrid, Spain

The Islamic Crossed-Arch Domes in Cordoba: Geometry and Structural Analysis of the “Capilla de Villaviciosa”

Crossed-arch domes are a singular type of ribbed vault. Their characteristic feature is that the ribs that form the vault are intertwined, forming polygons or stars, leaving an empty space in the centre. The earliest known vaults of this type are found in the Great Mosque of Córdoba, built ca. 960 A.C. The type spread through Spain, and the north of Africa in the tenth to the 16th centuries, and was used by Guarini and Vittone in the 17th and 18th centuries in Italy. However, it was only used in a few buildings. Though the literature about the structural behaviour of ribbed Gothic vaults is extensive, so far no structural analysis of crossed arch domes has been made. The purpose of this work is first to show the way to attack such an analysis within the frame of the Modern Limit Analysis of Masonry Structures and then to apply the approach to study the stability of the dome of the Capilla de Villaviciosa. The work may give some clues to art and architectural historians to understand better the origin and development of Islamic dome architecture.

Fouad Ghomari

Aboubekr Belkaid University, Tlemcen, Algeria

The Minaret of the Mosque of Mansourah: A Half-Ruin Elucidated

This study concerns an emblematic monument of the city of Tlemcen [Algeria]. This is the half-ruined minaret of the mosque of Mansourah, built in the medieval era [early 14th century], in pink sandstone freestone masonry and classified as National Heritage in 1900. This great architectural Merinid Heritage suffered partial damage that struck the popular imagination, which tried to elucidate the enigma through a legend. As part of that work, we try to provide a scientific response to this question, using 3D modeling for virtual reconstruction [photogrammetry method], based on available records, followed by an analysis of the mechanical behavior of the building, using the discrete element numerical method [3DEC calculation Code of Itasca]. Subject to degradation, the minaret loses its state of equilibrium and collapses. Of course, the entire entry vault collapses from the inside outward, making the center core tumble towards the mosque.

While falling, the latter will break out the southern and lateral sides halfway. The collapse occurred in a way as to have as an epilogue the same rupture line as the minaret. This allowed not only to confirm our baseline scenario but also to understand the collapse process in the emblematic half-ruined minaret.

Maria Teresa Como

Università degli studi Suor Orsola Benincasa, Naples, Italy

Structural Devices Concerning the Progressive Outer Shell Construction in Brunelleschi’s Dome

This study, through the interaction of analysis of sources and investigation of aspects of construction, statics and form, examines the initial construction phases of the S. Maria del Fiore dome which led to the building variations of the new program of January 1426 which resolved the realisation of semi-arches to be set among corner and middle ribs. The analysis highlights the essential static role of the mentioned constructional device, which together with the herringbone and the *corda blanda*, allowed the construction of the dome structure without the centering engendering the structural system of the rotational dome during the raising of the dome construction.

José Antonio García Ares, Ignacio Javier Gil Crespo

Polytechnic University of Madrid, Spain

The Ciborium or Lantern Tower of Valencia Cathedral: Geometry, Construction and Stability

Dating from the first half of the 15th century, this unique gothic lantern, erected over the transept of Valencia Cathedral, is a two-bodied octagonal masonry prism on conical pendentives topped with an octopartite brick vault on stone ribs. Its verticality and slenderness, together with an apparent lack of buttresses and an elaborated open tracery, confers it an airy character that greatly contrasts with the heaviness of the cathedral fabric. After presenting a historical outline of the cathedral works, the article analyzes the lantern’s geometrical configuration comparing it with the description provided by early 18th century author Vicente Tosca and with other modern sources. Considerations are made regarding the materials, construction methods and elements that configure the fabric to finish with an analysis of its stability. To this aim, an equilibrium approach within the theoretical framework of the lower bound limit analysis is adopted.

412. Transfer of Knowledge, Scientific Exchanges

Chair: **TBA**

Arturo Zaragoza Catalán

Academia de Bellas Artes de San Carlos de Valencia, Spain

José Calvo-López, Pau Natividad-Vivó

Universidad Politécnica de Cartagena, Spain

Stereotomic Exchanges between Iberia and France in the 16th Century: Benoît Augier, Valencian Stairways and the Escalier de Toulouse

One of the main archetypes of French stereotomy is *l’escalier de Toulouse*, a lost staircase in the *Capitole*, or town hall, built between 1531 and 1542 by Sébastien Bougureau from drawings by Benoît Augier. Jean-Marie Pérouse de Montclos and Bruno Tollon remarked that Bougureau had previously worked in Spain; recent research has shown that a Benet Augier was also active in Reus and Ontinyent, in Eastern Iberia. After a brief account of the Spanish work of Bougureau and Augier, this paper analyses a number of Spanish stairways, focusing on an example in Ontinyent. Next, it examines the Toulouse staircase, using as source material a number of drawings and photographs taken just before the demolition of the piece in 1885. The paper ends by discussing the implications of these examples in the broader picture of stereotomic exchanges between France and Iberia.

Hentie Louw

SAPL Newcastle University, UK

‘Machine pour ouvrir une fenêtre par contre-poids’: A Case Study Revealing the Nature of Invention and Innovation in Late-17th Century Northern European Architecture

The paper concerns an anonymous design for a counterbalanced vertically sliding wooden window, now known as the ‘sash window,’ found in the drawings collection of the French Huguenot architect/engineer, Jean de Bodt [1670-1745], in S.L.U.B Dresden. The drawing is attributed to Bodt and assumed to be for one of his Berlin projects of the first decade of the 18th century. With reference to previous research into historical fenestration, the author argues that this is in fact a French drawing of the mid-Louis XIV period – probably a lost ‘invention’ of the architect/scientist, Claude Perrault [1613-1688] – which may have served as a model for the practical implementation of the novel window type in Prussia where Bodt settled in 1699. The paper explores issues related to innovation and technology transfer in the field of architecture in a period of transition from medieval to modern industrial practices.

Fabio Tellia, Jose Carlos Palacios Gonzalo

Escuela Técnica Superior de Arquitectura, Universidad Politécnica de Madrid, Spain

The Squinch Vaults in Joseph Ribes’ Llibre De Trasas De Viax Y Muntea

The determination of the surface cladding of architecture often resulted from the availability of constructive techniques and materials as well as the cultural and social perspectives that architects sought to express, while the latter element is sometimes potentially more crucial. In this paper, the skeuomorphic link between structural brick and ornamental tile for the surface cladding of construction and for buildings in the westernised Far East is the focus. The social and cultural perspectives will be considered in significant examples, since these perspectives have strongly affected this structural morphology. This practice contained the diffusion and transfer of knowledge and of political power. Several architectural projects are examined in order to illustrate how these influences have played significant roles in the cladding of constructive elements, that is, walls, in the construction history of the westernised Far East.

Linnéa Rollenhagen Tilly

HTTP-CNAM, Paris, France

Knowledge of Architecture and Building Technologies in 18th Century Sweden

Two unpublished manuscripts of Carl Johan Cronstedt [1709-1777], superintendent of the Royal buildings in Sweden [1753-1767], record his use of his collection and library. These illustrated texts give new insights into the culture and the view upon building technologies and architecture in 18th century Sweden and Europe: the study of mainly French models by a Swedish architect, and their adaptation to the Scandinavian climate and building traditions. Through a selective bibliography and a modern footnote system, it is possible to follow not only Cronstedt’s readings, but also his personal observations and experiments – first as a young student travelling through Europe [1732-1737], then as an active architect at the Swedish Superintendency [1737-1767]. Classified according to subject areas, these manuscripts reveal the main concerns for a Modern architect-engineer which range from the aesthetical aspects of architecture, through technical issues, to a broader interest for urban infrastructures.

422. Politics & Policies

Chair: **Robert Carvais**, CNRS-Univ. Panthéon-Assas, Paris / ENS Architecture Versailles, France [TBC]

Roberto Eustaáquio Dos Santos

Universidade Federal de Minas Gerais, Brazil

The Plot of Concrete in Brazil: A History of the Technology Diffusion of Reinforced Concrete

Drawing upon a socio-historical view, this paper analysis the spreading of the building system of reinforced concrete and the development of its hegemony, in order to disclose the related network of influences [technical, economical and political]. It describes the main agents of such hegemony from the middle of the 20s until the end of the 30s: campaigns for professional affirmation and organisation of architects and engineers; academic reform; proliferation of consultancy and projects of architecture and engineering; creation of the Brazilian Standard Association and its first technical standards [which in fact concerned concrete]; reforms of urban regulation allowing high-rise buildings; industrialisation of civil construction; and, finally, an intense advertising campaign of the cement companies. Thus, this paper questions the belief that the intense use of concrete happens due to its structural performance, plastic qualities, and logistic and economic advantages.

Ricardo Tolosa, Jorge Galindo Díaz

Universidad Nacional de Colombia, Manizales branch, Colombia

Construction of Railway Workshops in Colombia during the First Half of the 20th Century: A National Engineering Triumph

This paper illustrates a technical debate regarding the construction project of the Chipichape Workshop of the Pacific Railway in Cali [Colombia] during the late 1920s and early 1930s. The Colombian government, of conservative ideology, projected the construction of the said shop with technical support from British mechanical engineer Paul C. Dewhurst and the German company Gutte Heffnungs Huette, which generated strong opposition from Colombian engineers, backed by liberal politicians. Finally, it was decided that Colombian engineers would execute the construction stemming from some prior experiences obtained in the construction of similar scale workshops from masonry walls and metallic and wooden roof structures. The paper show the technical debate that emerged during the phase prior to the construction process and covers the construction work [systems, materials] carried out, without leaving aside the biographical and professional training data of the

Colombian engineers who actively participated in directing the construction work.

Christel Frapier

Architectural Historian, Paris, France

Conceiving the Industrialization of Construction in France in the 1950s

After World War Two, France, like many European countries, faced an unprecedented housing shortage. Experiments carried out by the Ministry of Reconstruction and Urbanism failed to nip the housing crisis in the bud. France's commitment to the Marshall Plan in 1947 required an overhaul of its production methods, involving radical shifts in social attitudes and mentalities. The field of housing construction underwent great transformations, affecting architectural planning and on-site practices. To understand this evolution, we shall review the ways in which various French construction agencies imagined the industrialization of their trades. We shall demonstrate that the choices made were the result of international deliberation. We shall also examine the role played by leading engineers and architects in taking these decisions. Lastly, we shall observe how the pioneers of industrialization coped with the confrontation between their ideals and the reality of the construction sites.

Felipe Contier, Renato L.S. Anelli

Instituto de Arquitetura e Urbanismo da Universidade de São Paulo, São Carlos, Brazil

The Material Genesis of an Icon: The Construction of the Building of FAU USP [1961-1969]

This paper presents a study about the construction history of the building of Faculdade de Arquitetura e Urbanismo of the University of São Paulo [FAU USP] that took place between 1961 and 1969, a troubled period in the political and cultural life of Brazil. It is a relevant building to modern Brazilian architecture, designed by the architect Vilanova Artigas [1915-1985]. We seek to analyze in what way his conception of architecture is related to the construction processes of the period and guides a production, which is congruent with a national political project. The research is affiliated with new historical studies of Brazilian architecture, to which the understanding of the constructive process is part of the research method. The analysis of the architectural decisions,

both in the project and in the work in progress, demanded a wide documentary research [projects, documents, contracts, testimonies, photographic records] covering multiple agents [designers, contractors, builders].

430. Innovations in Reinforced Concrete

Chair: **Thomas Leslie**, Iowa State University, USA

Armande Hellebois, Yves Rammer, Jean-Claude Verbrugge

Building, Architecture and Town Planning Department, Ecole Polytechnique de Bruxelles, Université Libre de Bruxelles, Belgium
Concrete Piling: Major Developments in the Historical Practice of Pile Foundations

Since the dawn of civilisation, piles have either been widely used to increase the bearing capacity of weak soil conditions, or to reduce settlements under heavy constructions. For centuries, there was little change and timber was mostly used for deep foundations. At the end of the 19th century, concrete created a fundamental change in piling practice as demonstrated by the high number of patents taken out for various new kinds of piles. The reason for this lies in the properties of concrete: its high resistance to decay; its adaptability to various shapes, sizes and soil conditions; its limited responsiveness to vibration; and its high connectedness in structural systems. The present paper will analyse the first concrete piles mainly found in Belgium at the beginning of the 20th century according to type, method of execution, design and testing. This will be followed by addressing issues related to the reuse of ancient concrete piles, in order to assess their bearing capacity and safety level according to current standards.

Alessandra Bellicoso

Department of Architecture and Urban Planning, University of L'Aquila, Italy
Technological Innovation and Traditional Building Methods in the First Application of Reinforced Concrete in L'Aquila: The "New Provincial Insane Asylum" [1903-1916]

The construction of the "New Provincial Insane Asylum" of L'Aquila according to original plans is the first case of use of reinforced concrete in civil building in the city of L'Aquila. The preliminary plan drawn up in 1903 already contained precise indications concerning the construction method: load-bearing walls with reinforced-concrete subfloors and Holz-cement roofing. This was a highly innovative solution compared to the local building culture, so much so that the Provincial Administration invited some of the best specialized companies in Italy to participate in the private bidding for the reinforced-concrete work. The construction of the buildings is characterized by just this connection between

masonry and reinforced concrete that is much tighter than the separation of the bids for the two categories of work could lead one to think, and it involves, at the same time, both the organizational and the technical aspects.

John McGuinness

Maidenhead, UK
Air Raid Shelters in the United Kingdom 1939-1945: An Initial Investigation

This paper seeks to assess the state of technical knowledge available to the designers of shelters in the United Kingdom in 1938-1940 in anticipation of aerial attack and to describe the methods adopted for providing such shelter thereafter.

Pierre Jartoux

Association Eugène Freyssinet, Paris, France
Eugene Freyssinet's Life and Works [1879 -1962]

Freyssinet's engineering career began in the early 20th century, at a time when Portland cement was invented but not really used to make concrete for building. Even if the mechanical properties of this new material were barely known, Freyssinet was attracted to the material because of its moldability, simplicity of fabrication and low cost. In 1903, while visiting the cantilevers of the Rue de Rome in Paris built by Rabut, he became aware of one of concrete's major problems: cracking in the structure's strained parts. He drew two conclusions that subsequently underpinned his long career. The first one was that the concrete should be used in structural forms undergoing only compressive stresses. The second was the desire to control and eliminate cracking, which became possible with the invention of prestressed concrete, a new material that would "revolutionize the art of building". This paper will follow key inventions in order to situate in context Freyssinet's use of prestressed concrete in his numerous bridge and building projects.

431. Foundations & Masonry

Chair: **Maria Grazia D'Amelio**, Università Tor Vergata, Italy

Francisco Pinto Puerto, José María Guerrero Vega

University of Seville, Spain
The Scaenae Frons of the Roman Theatre of Itálica: Notes on the Construction Process

The studies conducted prior to the consolidation and recovery of the Roman Theatre of Itálica [Santiponce, Spain] have provided an opportunity to learn more about the historical evolution of the building as well as the processes and techniques used in its construction. The use of digital photogrammetry to take measurements and the detailed analysis of the fragments preserved have enabled us to establish the dimensions of the architectural orders with greater precision. We have also identified some of the original stone pieces used in the *columnatio* structure, which display traces of the original lime plaster subsequently covered with marble cladding secured with metal fixings. This not only confirms that the stage building underwent alterations but sheds new light on the building practices employed.

Maud De Voght, Krista De Jonge

University of Leuven, Belgium
Foundation Techniques in the Early Modern Low Countries [1600-1750]: A Problematic Case - St. Walpurgis in Antwerp

Archival sources exceptionally document the continuous degradation of St Walpurgis church at Antwerp [now lost] from the early 17th century onwards. Circa 1735, a thorough consolidation campaign became inevitable. Contemporary design drawings show ingenious techniques to increase the load-bearing capacity of the foundations to cope with differential settlements, such as a reversed arch system combined with foundation pits and wooden piles, and various systems for renewing and underpinning foundations. Comparison with earlier sources such as Charles De Beste, Simon Stevin and Cornille Le Coelre confirms the novelty of these solutions. Moreover, a system of iron tie rods suspended from the roof trusses was devised in order to rectify skewed walls and leaning columns, mirroring designs for new, large-span roof trusses known from the Jesuit context. Several well-known Antwerp architects, such as Guilliellmus Ignatius Kerrickx and Jan Pieter van Bourscheit [the Younger] seem to have been involved in the restoration works.

Philip S.C. Caston

Neubrandenburg University of Applied Sciences, Germany
The Pentagon Ramparts and Bastions of Fortress Rosenberg in Kronach, Germany

Fortress Rosenberg in Kronach, Bavaria, Germany, began life as a fortified stronghold. The 14th century saw its transition to a castle and, by the end of the 15th century, a second defensive ringwall with towers circumscribed Rosenberg. As the Thirty Years' War [1618-1648] loomed, Kronach's citizens began to transform the palace into a fortress. The inauguration of the work took place on 26 June 1656 and the pentagon was completed in the first decade of the 18th century. The construction history of the massive ramparts and bastions became the subject of an ongoing research project funded by the German Research Foundation in 2001. Whilst the general method of construction and the history of the ramparts has been determined, the purpose of the underground tunnels and breaks in the walls are still a mystery as are many other fine details.

Antonia Brauchle

Technische Universität Berlin and Stiftung LEUCOREA, Wittenberg, Germany
Cellars: Construction and Insulation through the Beginning of the 20th Century

Cellars as storage and utility areas are an indispensable constituent of domestic or economical units. Cellars prove to have a high degree of continuity compared to the rising construction, which is subject to great changes due to growing needs of comfort and representation. But even cellar constructions have different forms. Changes in domestic and economic work processes demand a new usage of cellars, thus demanding new structural engineering features. The different construction types of floors, walls, ceilings and vaults shed light upon particular construction stages on the one hand, but also express changing demands on storage space on the other. Various materials, methods and engineering skills were developed to meet and optimize these needs. Besides presenting a few typical construction forms, the emphasis of this paper lies on the specific demands on waterproofing cellars and insulating them against thermal radiation and moisture.

437. Metal Structures 2

Chair: **Stefan M. Holzer**, Universität der Bundeswehr München, Germany

Bernhard Heres

Brandenburg University of Technology, Cottbus, Germany
The Iron Structures in the Buildings of the State Hermitage St. Petersburg Erected 1838 – 1850: Forming Structures and Details in Early Structural Steelwork

Starting in 1838, after a devastating fire, iron structures were supplied for the rebuilding of almost all roofs and floors of the buildings in the palace complex of the Russian tsars [today the State Hermitage Museum St. Petersburg]. Successively erected by four manufacturers within a period of 13 years, these iron structures comprise a wide range of structures and details. They show the involved engineers' continued search for appropriate solutions for structures and details, and their step-by-step improvement – including failings and obscurities from today's point of view. As a result of recent surveys and documentation, several directions of development are perceptible. The paper presents concise examples concerning the design of trusses, the design of details and the joining technology as well as the origin and manufacturing technology of the iron profiles used.

Sergej Fedorov

Karlsruhe Institute of Technology, Germany
Rebuilding St. Petersburg's Winter Palace in the Context of Early European Steel Structures 1838-1850s: Contemporary Sources and Documents

Within a brief period after the disastrous fire of 1837, fireproof metal structures, very modern for the time, were erected in all the reconstructed edifices of the Imperial Winter Palace Complex in St. Petersburg [the current State Hermitage Museum]. Since 2009, the German Research Foundation [DFG] has been financing a first systematic survey and investigation of the Hermitage "structural ensemble." The proposed paper presents its results with regard to an analysis of Russian and French contemporary publications of the Winter Palace iron structures. A comparison of the unveiled drawings with the results of current measurements and observations makes it easy to understand the "structural design strategy" underlying the use of the new material, steel, in the construction practice followed at the beginning of the industrial revolution.

Donald Friedman, Old Structures Eng., New York City, NY, USA
Brian Bowen, Georgia Institute of Technology, Atlanta, GA, USA
Two Crystal Palaces: Constructive Technology and Practice; Great Britain 1851 – United States 1853

On 1 May 1851, an estimated 30,000 people witnessed the opening of the Exhibition of 1851 by Queen Victoria and Prince Albert in the Crystal Palace in Hyde Park, London. The success of the Exhibition and of the building that housed it led to ambitious proposals for expositions in New York, Dublin, Munich, Copenhagen and several British towns between 1851 and 1854. Most of the proposals were based on the glass and iron model; the most significant to proceed was an 1854 exhibition in New York in its own Crystal Palace. This paper explores similarities and differences in the design of the two buildings and the construction processes used to build them, with particular reference to the technological environment at that time in the two countries. The objective is to examine the conditions required for the introduction and adaptation of new technologies in construction.

Ines Prokop

Berlin University of the Arts, Germany
Wrought Iron and Steel Structures in Berlin in Their Prime from 1875 to 1925, with a Focus on Buildings for the Arts

The 19th century is generally considered to be the prime century of iron and steel construction. The simultaneous development of scientifically based calculation methods and iron and steel construction methods went hand in hand in ensuring the success of this materially efficient building method. The evolution of iron and steel construction in Berlin between 1875 and 1925 is illustrated in the following article by examples of the load-bearing structures of cultural buildings – such as museums, theaters and opera houses. These relatively unknown steel structures provide a framework within which the development of certain load-bearing structures can be illustrated. These include everything from the formation of statically determinate truss systems to statically indeterminate frame systems and varied structures for covered courtyards. The structural engineers Richard Cramer [1847-1906] and Otto Leitholf [1860-1939] had a significant influence on these developments in Berlin. Additionally, the resources available to the engineers at the time for planning their structures will be presented.

439. Interior Environment, Heating, Ventilation & Hygiene

Chair: **Joseph Tomlow**, Hochschule Zittau/Görlitz, Germany

Maaike Van Der Tempel, Ine Wouters, Filip Descamps, Dorien Aerts

Department of Architectural Engineering [ae-lab], Vrije Universiteit Brussel, Belgium
Innovations in Ventilation: Wind Cowls in the 19th Century

In the 19th century, innovative heat-induced low-pressure systems were introduced in public buildings and dwellings. These ventilation systems were enhanced by the addition of an air extraction element on the roof – a wind cowl – to inhibit counter flow and to amplify the air flow by maximizing wind effect. Different types of cowls were developed: fixed, mobile, revolving, symmetric, asymmetric, etc. Although the importance of wind cowls is often mentioned and discussed in 19th century manuals on ventilation and heating, only few designs are included in ventilation manuals and little has been written on the different hypotheses supporting the design, design parameters and problems encountered by engineers. Patents offer additional information when combined with knowledge of ventilation and designs mentioned in 19th-century manuals and contemporary insights. A survey of patent applications in Belgium is carried out to analyze wind cowls between 1830 and 1914.

Francesca Turri, Emanuele Zamperini

Building and Territorial Engineering Department, University of Pavia, Italy
The Military Engineers and Hygiene in Barracks in the Second Half of the 19th Century

Around the middle of the 19th century, doctors understood the role of living and working conditions, and of air and water quality in the health of population. Therefore medicine extended the focus from the patient to the hygiene of the built environment, leading to the birth of a new discipline: sanitary engineering. This subject had a strong influence on the design of barracks at different scales: urban location of settlements, morphology of the buildings, ventilation and dimensional standards of the dormitories, constructive details, and choice of materials. Since the early years after national unification, military engineers carried out studies and experimentation on this topic elaborating specific technical and hygienic criteria for the design of collective buildings. The paper finally focuses on the experimentation and application of new systems and devices for latrines to be used in barracks.

Dirk Van De Vijver

University of Utrecht, Netherlands
Hygiene in Belgian Architecture: The Case of Victor Horta [1861-1947]

During the 19th century, hygiene became a driving force for numerous conceptual and technical innovations in building [heating, ventilation, codes], building typologies [hospitals] and urbanism. In this paper, hygiene aspects of Horta's *oeuvre* are systematically addressed and situated in its specific Belgian context, in which research and innovation and the High Hygiene Council – crucial in the codification of hygiene principles in building construction regarding heating and ventilation, as well as in the construction of hospitals and housing programs – played an important part. The author addresses Horta as an architect [residences and the new Brussels Brugmann hospital] and as a technocrat. As a member of the High Hygiene Council, the Council on Monuments and Sites and the Belgian Academy, Horta reflected on general policies and regulations. This research is based upon his built *oeuvre* and exploits both published papers and unpublished writings [Horta Museum].

Emmanuelle Gallo

HTTP-CNAM / ENSA Paris-Belleville, France
Scientific Developments of Heating and Ventilation Professional Unions and Learned Societies in France during the First Part of the 20th Century

Professional unions of stove manufacturers appeared, in 1817, followed by central heating constructors. After 1918, unions and learned societies interested in heating and ventilation multiplied initiatives and set up committees in order to solve the big problem of the time: a significant deficit of energy sources. The unions and learned societies performed experiments on heating surfaces and new fuels, oversaw specialized education curricula, published theoretical and practical literature and held regular congresses, and organized public exhibitions to democratize heating systems. Those different activities represent an increase in the technical proficiency of central heating manufacturers and engineers: from experimental, the field became almost scientific. Heating and ventilation technologies were the first to be industrialized in the construction sector. All these developments are a prelude for post-war building organizations, when industrialization and the scientific method became a necessity in the entire construction sector.

Session Index

Applied Sciences 1 [406] / 23, 26
Applied Sciences 2 [407] / 55, 56
Architectural & Structural Design 1 [404] / 3, 5
Architectural & Structural Design 2 [405] / 13, 15
Brick & Tile [423] / 3, 10
Construction History, Education & Diffusion [402] / 13, 14
Construction History, Epistemology & Historiography [401] / 3, 4
Construction History, Heritage & Restoration [403] / 23, 24-25
Construction History, Sources & Methods 1 [302] / 65, 66
Construction History, Sources & Methods 2 [301] / 73, 74
Contractors [416] / 13, 16
Craftsmanship & Technical Tasks [311] / 65, 70
Craftsmanship, Gender, Individuals & Communities [415] / 3, 7
Deconstruction & Reconstruction [314] / 47, 51
Earthen & Plaster Structures [427] / 35, 43
Foundations & Masonry [431] / 81, 87
Hydraulics [443] / 13, 21
Industrialization & Rationalization [440] / 3, 11-12
Infrastructure & Public Works [322] / 73, 80
Infrastructure & Public Works, Bridges [444] / 23, 32
Infrastructure & Public Works, Transportation [445] / 35, 46
Innovations in Reinforced Concrete [430] / 81, 86
Institutions [421] / 55, 59
Interior Environment, Heating [438] / 55, 64
Interior Environment, Heating, Ventilation & Hygiene [439] / 81, 89
Interior Environment, Lighting [318] / 73, 78
Labor Market [312] / 73, 76
Management of the Construction Site [419] / 55, 58
Metal [315] / 65, 71
Metal Structures 1 [317] / 47, 53
Metal Structures 2 [437] / 81, 88
Mortar [428] / 55, 60
Natural & Technical Risk, Earthquake Design [442] / 35, 45
Organization of the Construction Site [417] / 23, 29
Ownership of Property [313] / 73, 77
Politics & Policies [422] / 81, 84-85
Prefabrication 1 [441] / 13, 20
Prefabrication 2 [320] / 65, 72
Real Estate Market [The], the Cost of Construction [420] / 3, 8-9
Reinforced Concrete, Reception & Dissemination [429] / 55, 61
Reinforced Concrete, The Hennebique Companies [316] / 47, 52
Reuse & Recycling [426] / 35, 41-42
Rules & Standards, Architectural and Urban Norms [305] / 65, 67
Rules & Standards, Building Regulation Compared [306] / 23, 33
Rules & Standards, Specifications [304] / 47, 49
Saving & Recovery Energy [319] / 73, 79
Scaffolding and Machines [418] / 35, 40
Shells & Thin Vaults [434] / 35, 44
Stone [425] / 23, 30
Structural Analysis & Modeling 1 [410] / 35, 36-37
Structural Analysis & Modeling 2 [408] / 55, 57
Structural Analysis & Modeling 3 [409] / 81, 82
Structural Bricks & Tiles [424] / 13, 17
Technical Literature, Images & Representation [414] / 35, 38-39
Technical Literature, Manuscripts [309] / 65, 69
Technical Literature, Publications [310] / 47, 50
Training & Education 1, Engineers [308] / 65, 68
Training & Education 2, Architects [307] / 73, 75
Transfer of Knowledge, Colonial Situations 1 [411] / 3, 6
Transfer of Knowledge, Colonial Situations 2 [303] / 47, 48
Transfer of Knowledge, Political Initiatives [413] / 23, 27-28
Transfer of Knowledge, Scientific Exchanges [412] / 81, 83
Vaults & Stereotomy 1 [432] / 13, 18
Vaults & Stereotomy 2 [433] / 23, 31
Wood Structures 1 [436] / 13, 19
Wood Structures 2 [435] / 55, 62-63

People Index

- Abrantes, V.T. 77
 Acker, P. 52
 Addis, B. 15, 57
 Aerts, D. 89
 Ajayi, R. 24
 Albuerne, A. 57
 Alonso-Rodríguez, M.Á. 18, 31
 Amici, C.M. 80
 Anaya Díaz, J. 61
 Anelli, R.L.S. 84-85
 Antón Barco, M. 5
 Antonini, A. 43
 Artola Blanco, M. 77
 Atzbach, R. 64
 Avenier, C. 61
 Bachmann, M. 41
 Bailiff, I. [See Guibert]
 Baker, N. 7
 Balboni, L. 78
 Baltazar, A.P. 70
 Ban, S. 35
 Barber, D.A. 79
 Barber, J. 30
 Barbot, M. 8
 Barelli, L. 29
 Barjot, D. 3, 16
 Baylé, M. [See Guibert]
 Becchi, A. 55
 Beech, N. 51
 Bellicoso, A. 86
 Bernardi, P. 51, 71
 Bertels, I. 16, 40
 Bertolazzi, A. 30
 Bianchini, C. 56
 Bird, R. 6
 Blain, S. [See Guibert]
 Boiardi, L. 43
 Bonavita, A. 29
 Boulerice, D. 5
 Bouvier, A. [See Guibert]
 Bowen, B. 49, 88
 Brauchle, A. 87
 Bravo Guerrero, S.C. 14
 Brocato, M. 57
 Bryon, H. 38-39
 Bühler, D. 74
 Buonopane, S. 19
 Burt, R. 51
 Büttner, S. [See Guibert] 41, 51
 Caldas, J. 45
 Caldenby, C. 76
 Calvo-López, J. 18, 31, 83
 Campbell, J.W.P. 5, 62, 64
 Campisi, T. 45
 Carvais, R. 33, 67, 84
 Cassinello, P. 44
 Caston, P.S.C. 87
 Cavers, G. 30
 Çelik, G. 70
 Chatzikonstantinou, E. 46
 Chauvin, A. [See Guibert]
 Chrimes, M. 68
 Ciblac, T. 36
 Cirera, L. 36
 Clarke, L. 4, 76
 Cluzel, J.-S. 38
 Cofani, M. 60
 Collette, Q. 16
 Como, M.T. 82
 Conchon, A. 29
 Conlon, C. 44
 Contier, F. 84-85
 Cook, E. 70
 Cooke, T. 57
 Cormier, A. 15
 Cornilly, J. 49
 Corradini, P. 78
 Coste, A. 61
 Cox, R. 50
 Currà, E. 61
 D'Alençon, R. 27
 D'Almeida, C.H. 74
 D'Amelio, M.G. 38, 87
 Dandria, S. 19
 Daneels, A. 43
 Davidovits, F. 60
 De Cesaris, F. 38
 De Jonge, K. 68, 87
 De Voght, M. 87
 Decri, A. 21
 Del Curto, D. 80
 Delaine, J. 57
 Delemontey, Y. 72
 Descamps, F. 89
 Dessales, H. 45
 Devos, R. 52
 Dillmann, P. 71
 Dimitriadi, L. 11-12
 Diodato, M. 43
 Dobraszczyk, P. 71
 Domenech Casadevall, G. 7
 Douard, P. 21
 Dufresne, P. [See Guibert]
 Dunkeld, M. 14, 59
 Ebright, S. 19
 Er Akan, A. 27
 Eres, Z. 62
 Espion, B. 53
 Esposito, D. 51
 Eßer, G. 10
 Etlin, R.A. 5, 18
 Faliva, M. 66
 Fallacara, G. 31
 Fares, K. 11
 Fatta, G. 45
 Fedorov, S. 24, 88
 Fernández Correas, L. 40
 Fernandez, V. 11
 Ferrari, I. 32
 Février, P. 27
 Fleury, F. 19, 26
 Foce, F. 56
 Fonkenell, G. 71
 Fracchia, B.M. 49
 Franceschelli, S. 26
 Frapier, C. 84
 Freitas, M.L. de 16
 Friedman, D. 88
 Fuentes, P. 82
 Galindo Díaz, J. 48, 84
 Gallo, E. 64, 89
 García Ares, J.A. 82
 García Erviti, F. 8-9
 García García, R. 20
 García Soriano, J. 43
 Garcia-Alonso, M. 16
 Gasparini, D.A. 32
 Ghoche, R. 15
 Ghomari, F. 82
 Gil Crespo, I.J. 82
 Gil López, T. 18
 Girón, J. 38, 50
 González Redondo, E. 67
 González-Longo, C. 7
 Graciani, A. 74
 Graf, F. 24-25
 Grau Giménez, C. 43
 Greco, L. 20
 Grimoldi, A. 56
 Gueli, A. [See Guibert]
 Guerrero Vega, J.M. 87
 Guerrero-Baca, L.F. 43
 Guibert, P. 66
 Guillemard, F. 20
 Guillaume, A. 29
 Gulli, R. 43
 Gzowska, A. 59
 Halpérin, J.-L. 77
 Harrer, A. 62
 Heald, A. 30
 Heinz, R. 60
 Hellebois, A. 86
 Heres, B. 88
 Hernando de la Cuerda, R. 11
 Hernu-Belaud, J. 67
 Heyman, J. 31, 57
 Hnilica, S. 72
 Holzer, S.M. 19, 32, 88
 Honda, Y. 21
 Hoshino, Y. 46
 Hsu, H.-Y. 48
 Hsu, M.-F. 6
 Huerta, S. 36-37, 82
 Ibarra-Sevilla, B. 6
 Iori, T. 14
 Isaac, C. 58
 Jager, M. 72
 Janssen, J. 76
 Jartoux, P. 86
 Jenkins, M. 10
 Kahlow, A. 56
 Kapp, S. 70
 Kavas, K.R. 70
 Kitagawa, D. 46
 Klosky, L. 13, 40
 Kobayashi, I. 21, 41-42
 Koetz, L. 15
 Korwan, D. 27
 Koury, A.-P. 59
 Krauskopf, C. 62-63
 Küçükdoğan, B. 27
 Kurapkat, D. 62
 Kurrer, K.-E. 32, 71
 L'Héritier, M. 71
 Lambert, G. 68, 75
 Lancaster, L.C. 10, 64
 Landi, A. 78
 Lanos, P. [See Guibert]
 Laux, E.-L. 76
 Leslie, T. 61, 86
 Lewis, M. 10
 Linssen, W. 68
 Lisboa, R. 45
 Llopis Pulido, V. 72
 Lloyd Thomas, K. 49
 López-Mozo, A. 18
 Lorenz, W. 14, 53
 Louw, H. 66, 83
 Maciá Sánchez, J.F. 8-9
 Maejima, M. 27-28
 Makrodimitri, M. 64
 Malaquin, A. 8
 Mandat-Grancey, J. de 30
 Manfredi, C. 64, 79
 Marconi, N. 40
 Marino, G. 78
 Martin Talaverano, R. 31
 Martinez-Gonzalez, J. 16
 Martini, M. [See Guibert]
 Mascarenhas-Mateus, J. 4, 74
 Mastroilli, A. 26, 56
 Mathé, V. 8
 May, R. 14, 44
 McDonough, K. 29
 McGuinness, J. 86
 McGuire, C. 76
 Meehan, T. 59
 Melo, A. 8, 58
 Menchetti, F. 69
 Meyer, T. 4
 Middleton, R. 73, 75
 Mileto, C. 43
 Minault-Richomme, E. 50
 Miyake, R. 27-28
 Mondardini, L. 57
 Montelli, E. 41
 Moreno Puchalt, J. 72
 Moser, J. 27
 Mosthtaghe Gohari, K. 79
 Muñoz Soria, G. 17
 Muñoz, R. 80
 Nagamura, K. 21
 Nakama, K. 41-42
 Natividad-Vivó, P. 83
 Nègre, V. 70, 75
 Nijland, T.G. 30
 O'Dwyer, D. 50
 Ochsendorf, J. 17, 44, 57
 Odiaua, I. 24
 Okada, S. 41-42, 46
 Örmecioglu, H.T. 27
 Özdoğan, E. 62
 Palacios Gonzalo, J.C. 14, 83
 Paliza Monduate, M.T. 33
 Palomares Figueres, M. 72
 Papavasileiou, S. 64
 Paternò, D.L. 24
 Pelissetti, L.S. 69
 Pelke, E. 32
 Peñalver Martínez, M.J. 8-9
 Pereira, M. da S. 48
 Perez de los Rios, C. 31
 Pesce, G.L.A. 66
 Peters, T.F. 17, 24
 Petit, J. 16,
 Petralla, S. 31
 Pinon, M. 29
 Pinto Puerto, F. 87
 Poretti, S. 14
 Porrino, M. 46, 80
 Prado, F. 27
 Prigent, D. [See Guibert]
 Prokop, I. 88
 Puget, J. 33
 Quantrill, A. 6
 Quatember, U. 18
 Quist, W.J. 30
 Rabasa Díaz, E. 5, 18, 31
 Rabeneck, A. 61
 Radelet-de Grave, P. 26, 36
 Ramírez Pacheco, G. 8-9
 Rammer, Y. 86
 Rauhut, C. 50
 Redondo Martínez, E. 17
 Ribeiro, M. do C. 8
 Robson, K.F. 58
 Rociola, G. 19
 Rodríguez García, A. 15
 Rodríguez Romero, E.J. 5
 Roesler, S. 4
 Roff, S.E. 7
 Rollenhagen Tilly, L. 83
 Romero Bejarano, M. 58
 Romero Medina, R. 58
 Rousteau-Chambon, H. 75
 Ryan, R.C. 40
 Sağ, K. 30
 Sakarovitch, J. 69, 41
 Sakellaridou, A. 46
 Samarinis, P. 46
 Sampaoli, G. 78
 Saner, T. 30
 Sanjurjo Álvarez, A. 18
 Santos, R.E. dos 84
 Sapin, C. [See Guibert]
 Sassa, A. 45
 Schlimme, H. 26, 52
 Senent Domínguez, R. 31
 Shelton, T. 46
 Sibia, E. [See Guibert]
 Silva-Contreras, M. 52
 Simmonot, N. 78
 Šimunić Buršić, M. 18
 Slivnik, L. 53
 Smith, A. 19
 Sroor, M. 33, 77
 Stegmann, K. 4
 Stella, G. [See Guibert]
 Suarez, J. 36
 Suits, M. 44
 Tabarrini, M. 69
 Taiwo, A.A. 24
 Talenti, S. 68
 Tamayo, B. 58
 Tamborero, L. 26
 Tanaka, N. 21, 46
 Tedeschini, M.R. 43
 Tejela Juez, J. 5
 Tellia, F. 83
 Theodossopoulos, D. 7, 30, 43
 Thuswaldner, B. 18, 60
 Timbert, A. 71
 Togliani, C. 21
 Tolosa, R. 84
 Tomlow, J. 89
 Toso, F.C. 80
 Trautz, M. 27
 Travaglio, P. 69
 Troja, O. [See Guibert]
 Turri, F. 89
 Vacher, H. 6, 48
 Vale, C.P. do 77
 Van de Vijver, D. 89
 Van de Voorde, S. 52
 Van der Tempel, M. 89
 Vargas, H. 20, 72
 Vargas, M.F. 27
 Vecchiattini, R. 66
 Vegas, F. 43
 Verbrugge, J.-C. 86
 Verswijver, K. 16
 Villate, C. 58
 Vinci, C. 45
 Voigts, C. 19
 Voormann, F. 27
 Wall, C. 76
 Wannous, S. 79
 Weber, C. 59
 Webster, S.V. 7, 81
 Wendland, D. 36
 Wermiel, S. 10
 Wetzck, V. 20, 53
 Williams, M. 57
 Wouters, I. 16, 89
 Wu, N.-W. 17
 Wünnemann, A. 19
 Yao, B.-H. 6
 Yoda, T. 32
 Zakia, S.A.P. 67
 Zamperini, E. 89
 Zaragoza Catalán, A. 83
 Zastavni, D. 14
 Ziegler, V. 59
 Zessin, J. 17
 Zhao, C. 38



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