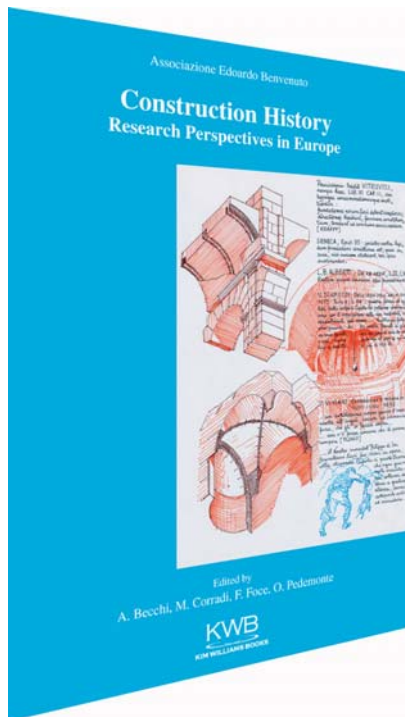


Patricia Radelet-de Grave The Meaning of “Between Mechanics and Architecture”

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Construction History Research Perspectives in Europe

A. BECCHI, M. CORRADI, F. FOCE AND O. PEDEMONTE, EDS.

This is vol. IV in the book series “Between Architecture and Mathematics”. The Associazione Benvenuto for research in the Science and Art of Building in their historical development assigned to a few international “observers” the task of styling a map of Construction History in their various countries. Obviously, we are not dealing here with an exhaustive map, but rather with a first attempt to identify some of the significant lines of research and to put into contact the individual scholars. A small step towards the constitution of an international scientific community that is interested in architecture as well as mechanics; in construction as well as its history. A community which, up to the present, has not known how to find the essential points of contact and dialogue, and which has avoided the onus of long-term initiatives. The present volume is an aid for establishing solid collaborative research projects, knowing that this can happen only if the studies are so rigorous and detailed that those emphatic recall to arms of interdisciplinarity, sure signs of problems set forth badly, are rendered superfluous.

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WHAT IS THE MEANING OF “BETWEEN MECHANICS AND ARCHITECTURE”?

Patricia Radelet-de Grave

Introduction

In Bressanona, at the ceremony to award the first Edoardo Benvenuto Prize,¹ I tried to point out the many different fields that influence architecture—artistic, mathematical, technological, sociological—in order to be able to focus on the interaction that Edoardo Benvenuto and I named “Between Mechanics and Architecture”. Here I wish to define more precisely what this title means, and what it includes.

First I have to point out an essential aspect of this study which, regrettably, does not appear in the title: history. In fact, the understanding of the actual relationship may be facilitated by the analysis of the historical relationships between the science of mechanics and the art of architecture, throughout the ages.

1 Interaction between mechanics and architecture

The richness of the relationship between mechanics and architecture arises from the fact that it is an interaction, rather than an influence of one upon the other. Architecture did more than borrow knowledge from mechanics, it also stimulated mechanics. In his introduction to the first volume of the book series “Between Mechanics and Architecture”, EDOARDO BENVENUTO explains the stakes of this interaction and concludes:

...Henceforth the alternative is no longer between science and art, but between two different epistemological positions: and it is not an alternative but a productive, although tricky, encounter, the history of which is very rich and probably unexplored as yet.²

¹ The ceremony took place in Bressanona, during the XVIII Congress “Scienza e Beni Culturali,” 4 July 2002.

² P. RADELET-DE GRAVE and Edoardo BENVENUTO, *Between Mechanics and Architecture*, Basel, Birkhäuser, 1995, p. 18.



Fig.1: Man needed tools to lift the stones for this dolmen (between 4000 and 2000 B.C.)

From the beginning of time, architecture influenced studies of mechanics. Evidence is given by the first mechanic law of the lever, set by ARISTOTLE and ARCHIMEDES, and by the first axiomatic theory of mechanics which assembles, through the lever law, all the simples machines—i.e., all the lifting devices—which were essential for the construction of houses and sacred buildings. These studies would lead in 1687 to statics, the name given by VARIGNON to the study of simple machines. With his *Eléments de statique*,³ this subject would be taught by POINSOT, in 1803, to the students of the prestigious Ecole Polytechnique in Paris, marking a turning point in the interaction between mechanics and architecture.

Hydrostatics too, born in ancient times from the need to convey water, developed together with hydrodynamics, as an answer to engineers' and architects' needs: the first step towards the mechanics of continuous media.

But before that, other influences arose. At the end of Middle Ages, GALILEO himself, who observed the construction of Gothic churches, drew inspiration from the many problems brought out by the builders. Studies on clamped beams, catenaries, and beams on three supports were all initiated by him and

³ L. Poinsot, *Eléments de statique*, Paris, Callixte-Volland, 1803. This book was reprinted many times.

further studied in the seventeenth and eighteenth centuries by the most important mechanical engineers: LEIBNIZ, JACOB, JOHANN and DANIEL BERNOULLI, LEONHARD EULER, and many others. All applied themselves to the development of differential calculus: an essential tool for solving the most complex problems. These mechanics, in turn, made possible the construction of new machines and the building of new architecture. The achievements of these researches would be collected by LAGRANGE, POINSOT, POISSON, CAUCHY, and other famous professors of the Ecole Polytechnique, granted with much more sophisticated mathematics, who would contribute to the progress of mechanics. Mechanics would thereon develop in a more independent way, as a science of its own, apparently liberated from applicative problems. Nevertheless, the Ecole Polytechnique still is an engineering school. The consequence would be the inversion of relationship. Architecture would no longer really influence mechanics, but mechanics—the better knowledge of materials, of their strength—will offer new possibilities to architects and engineers. And this interaction still exists nowadays.

It is the history of these mechanics, born from the demands of architecture, and developed together with architecture and the art of building, that Edoardo Benvenuto and I intended to study, in what was meant to be only one conference, whose proceedings, entitled *Between Mechanics and Architecture*, were published by Birkhäuser in 1995.

2 Sources, influences, previous works

Of course, Benvenuto and I, and the people we invited to this first conference, were not starting from nothing. Some important authors provided us with solid bases, even if their point of view was not always absolutely similar to ours.

BENVENUTO, Edoardo. 1991. *An introduction to the history of structural mechanics*. Springer-Verlag: New York. This book is divided in two parts: I. Statics and resistance of solids and II. Vaulted structures and elastic systems (Fig. 2).

LOVE, H.A.E. 1892. “Historical Introduction,” *Treatise on the mathematical theory of elasticity*, Cambridge.

TODHUNTER, Isaac and Karl PEARSON. 1886 and 1893. *History of the theory of elasticity and of the strength of materials*. 2 vols. Cambridge: Cambridge University Press.

TIMOSHENKO, Stephen P. 1953. *History of strength of materials, with a brief account of the history of theory of elasticity and theory of structures*. New York: McGraw-Hill.

TRUEDELL, Clifford. 1960. The rational mechanics of flexible or elastic bodies 1638-1788. *Leonhardo Euleri Opera Omnia*. Zürich: Orell Füssli. Introduction to vols. 10 and 11 *Leonhardo Euleri Opera Omnia*, which regards elasticity.

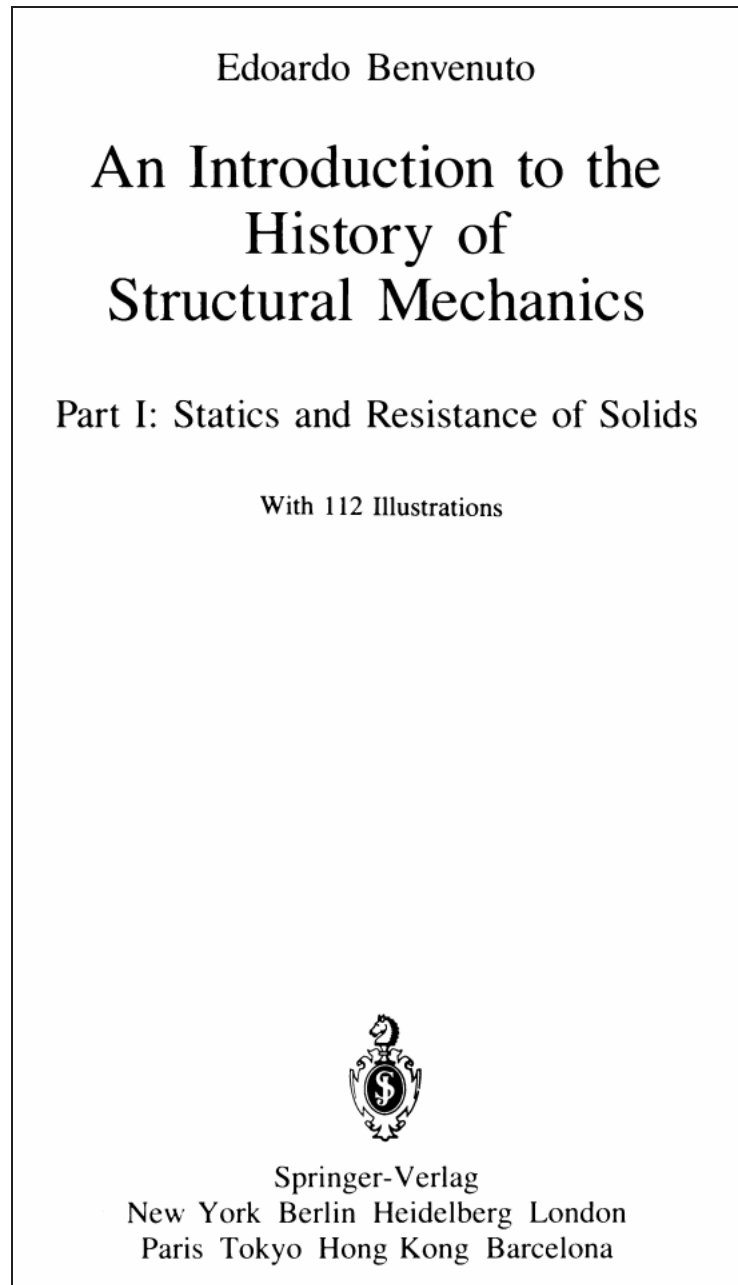


Fig. 2. Frontispiece of the book by Edoardo Benvenuto

3 The new works

This idea, “between mechanics and architecture,” did not result in just one conference, but five. The first one took place in Saragossa⁴ and had the original title “Between Mechanics and Architecture.” Then we first went to Genoa for the meeting entitled “Culmann and Graphostatics,” next to Liège for “Between Mechanics and Architecture in Encyclopaedia,” then to Louvain-La-Neuve for “Saint-Venant,” and then to Pescara for “Perspective.” Until now the original idea has resulted in the publication of three books, of which we will speak later. Others are in preparation.

With time, our small group came to meet other scholars whose research shared an affinity with ours. Among others, I may name JACQUES HEYMAN for his studies on the history of structural mechanics; SANTIAGO HUERTA and his team, organizers of the First International Congress on Construction History (Madrid, 20-24 January 2003); PIERRE SMARS, JOHN OCHSENDORF, and TULLIA IORI, whose theses were awarded the Edoardo Benvenuto prize for the years 2002 and 2003, respectively; and KIM WILLIAMS, who is interested in the more general relationships between architecture and mathematics, and who is taking care of the publication of the present volume.

4 Bibliography

This wide group produced many publications. I wish to point out, classify and comment with a few words those which meet our goal more closely.

4.1 Monographs

We will start with six monographs, five of which are mainly dedicated to vaults and domes.

HEYMAN, Jacques. 1972. *Coulomb's memoir on statics. An essay in the history of civil engineering*. Cambridge: Cambridge University Press. (In this book, Heyman offers a fac simile, a translation and a profound reflection on the famous text by Coulomb, *Essai sur une application des règles de Maximis et Minimis à quelques problèmes de statique relatifs à l'architecture*)

HEYMAN, Jacques. 1995. *The stone skeleton*. Cambridge: Cambridge University Press. (Spanish translation, CEHOPU, 1999). (Here Heyman studies stone vaults and domes from still existing buildings and ancient treatises.)

⁴ During the XIXth international meeting on history of science. I wish to recall here the name of the Spanish organizers of this meeting: Elena Ausejo and her husband Mariano Hormigon who unfortunately left us a short time ago.

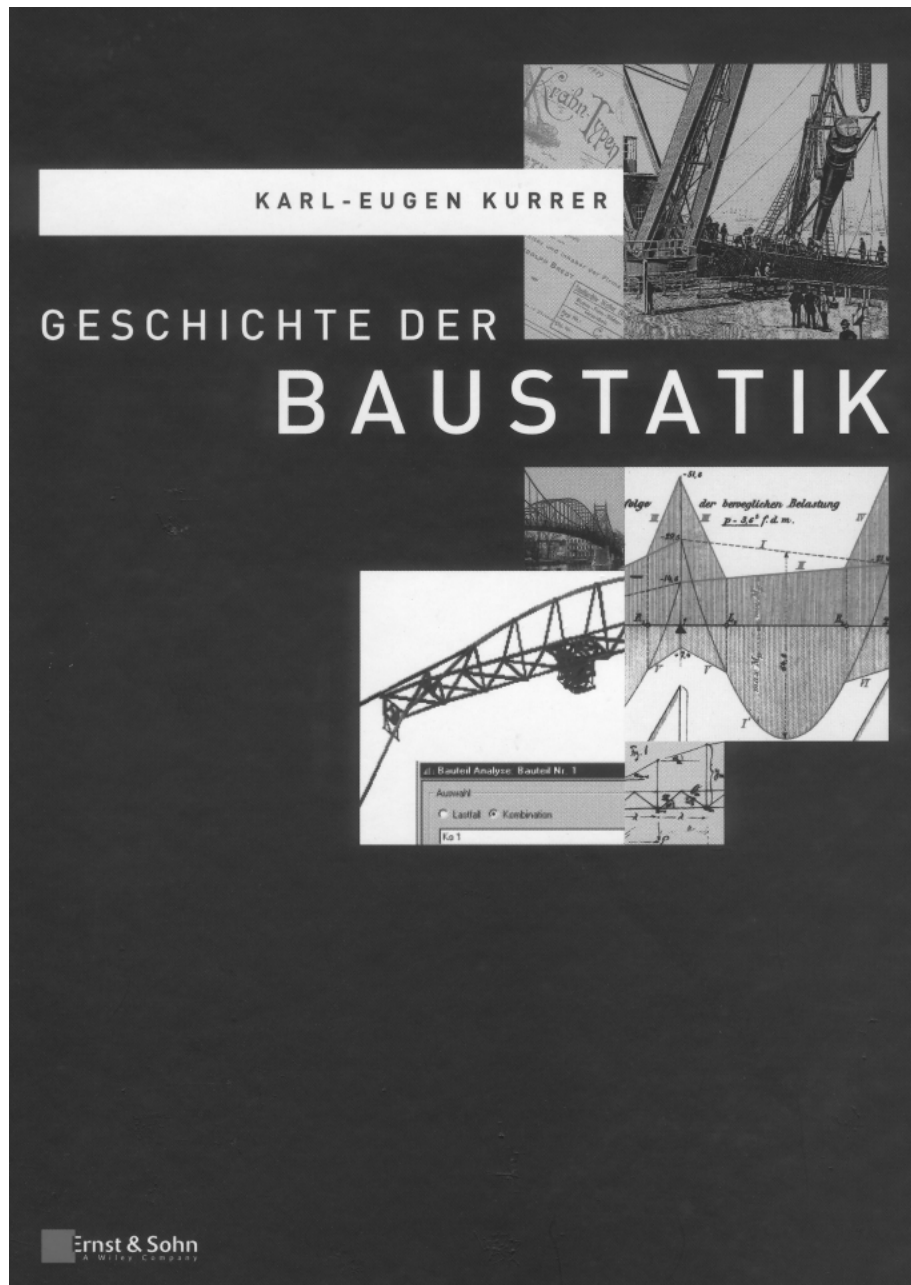


Fig. 3. Frontispiece of the book by Karl-Eugen Kurrer

DI PASQUALE, Salvatore. 1996. *L'arte del costruire. Tra conoscenza e scienza*. Venice: Marsilio. (The results of many years of studies on the dome of Santa Maria del Fiore in Florence and on masonry structures are collected in this book. It is the work of a building site man, a professor who likes to understand buildings from an historical approach.)

SMARS, Pierre. “Etudes sur la stabilité des arcs et des voûtes, confrontation des méthodes de l'analyse limite aux voûtes gothiques du Brabant.” Thesis, Catholic University in Leuven. (Smars makes a survey of all the Gothic vaults of Brabant, Belgium, studying each of them in detail as to their particularity and stability, and executes a meticulous analysis of their damage (cracks). This thesis was awarded the Edoardo Benvenuto prize in 2002.⁵)

BECCHI, Antonio and Federico FOCE. 2002. *Degli archi e delle volte. Arte del costruire tra meccanica e stereotomia*. Venice: Marsilio. (This book analyses the relationship between architecture and stereotomy, a science whose development is tightly linked to the evolution of perspective.)

KURRER, Karl-Eugen. 2002. *Geschichte der Baustatik*. Berlin: Ernst and Sohn. (Kurrer gives an historical presentation from the standpoint of engineering, whereas Benvenuto, in his own book, follows mechanics' principles and chooses the advent of iron to mark the division between his two volumes. Kurrer's book is rather oriented towards iron architecture. It includes very interesting short biographies of the major engineers and architects. See Fig. 3.)

Soon the works that were awarded the second edition of the Benvenuto Prize will join these monographs:

OCHSENDORF, John. 2002. “Collapse of masonry structures.” Ph.D. thesis, Cambridge University Engineering Department.

IORI, Tullia. 2001. *Il cemento armato in Italia dalle origini alla seconda guerra mondiale*. Rome: EdilStampa.

4.2 Books of collected papers

RADELET-DE GRAVE, P. and E. BENVENUTO, eds. 1995. *Between Mechanics and Architecture*. Basel: Birkhäuser. (In addition to the papers of which we will speak later on, the reader may find here a number of other modern and historical references, all pertinent to the subject. Through the bibliography, prepared by Antonio BECCHI, Massimo CORRADI, and Federico FOCE, the reader can get a very precise definition of the subject. See Fig. 5.)

GRACIANI GARCÍA, A., S. HUERTA FERNANDEZ, E. RABASA DÍAZ, and M.A. TABALES RODRIGUEZ, eds. 2000. *Actas del Tercer Congreso Nacional de Historia de la Construcción*, 2 vols, CEHOPU. (The subject of this book is the construction site. It investigates mainly its social aspects.)

⁵ BRUNA GAINO came in second at this first edition of the prize, presenting a thesis from Louvain Catholic University, entitled “Du tensor de W. Voigt au sistema covariante de G. Ricci: différentes origines pour un même concept”.

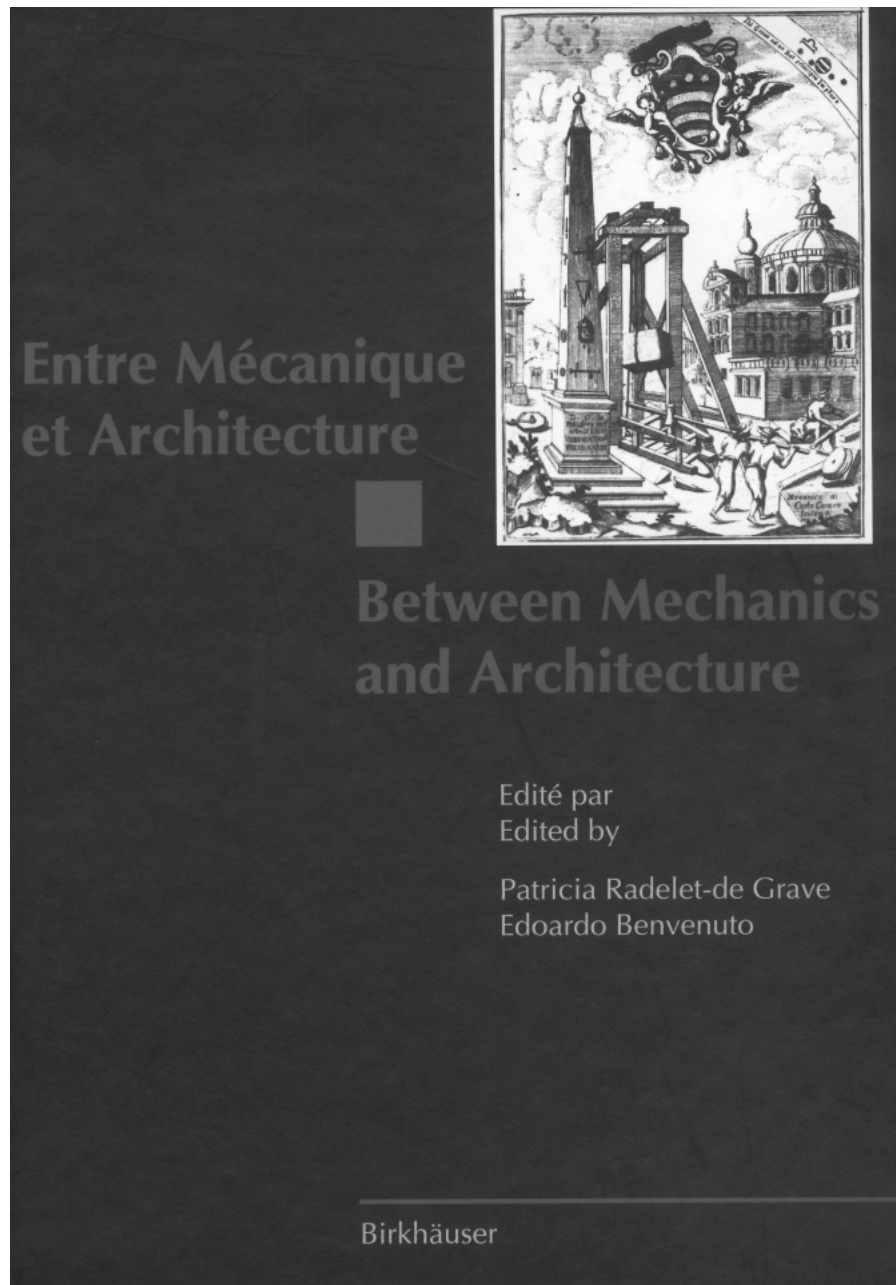


Fig.4: Frontispiece of the first volume of *Entre Mécanique et Architecture*

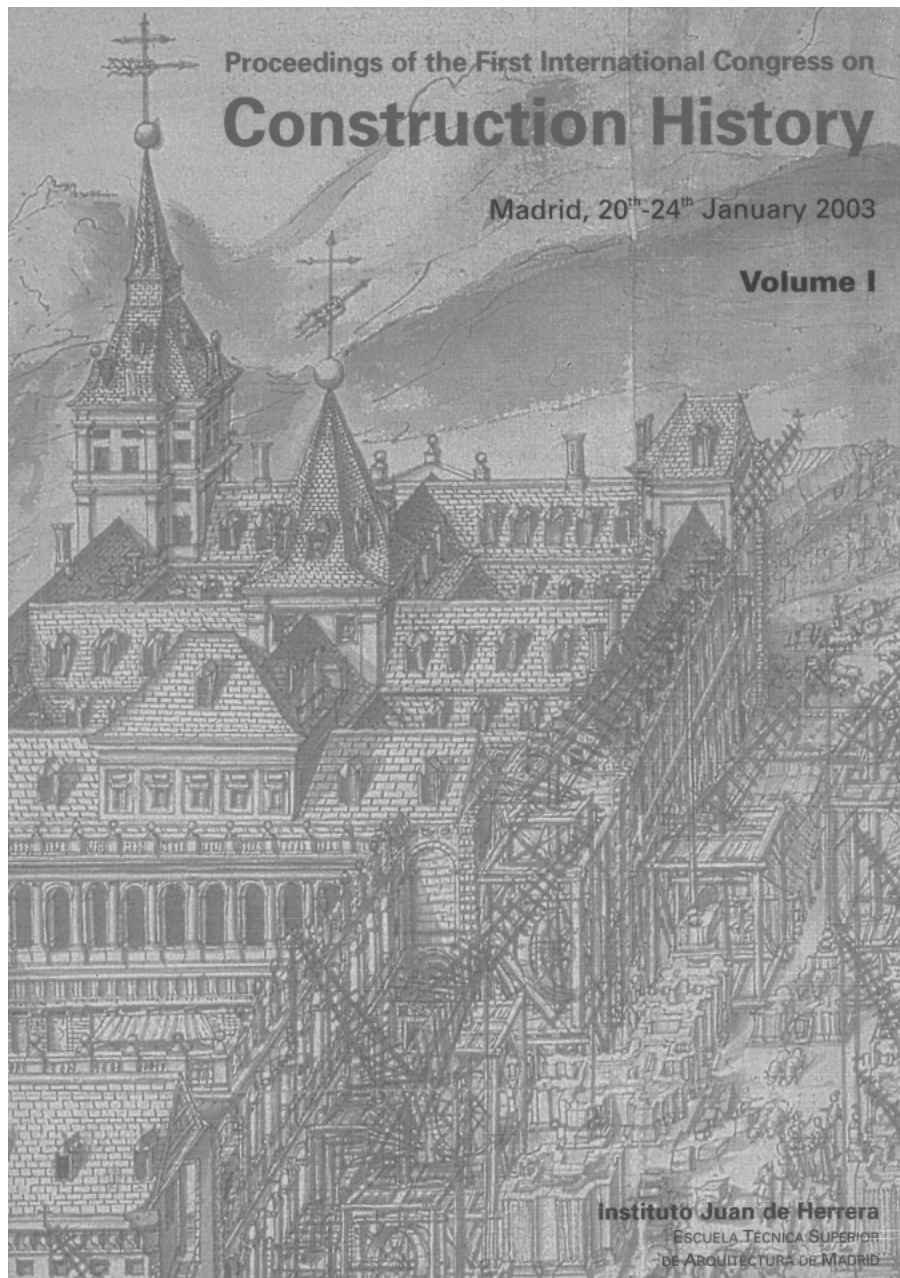


Fig. 5. Frontispiece of the
Proceedings of the International Conference of Madrid

- HUERTA, S., ed. 2003. *Proceedings of the First International Congress on Construction History*, 3 vols. Madrid: Instituto Juan de Herrera. (These three big volumes include many papers pertinent to our subject. We will return to them later on. See Fig. 5.)
- BECCHI, A., M. CORRADI, F. FOCE, and O. PEDEMONTE, *Towards a history of construction*. Birkhäuser, Basel 2003. (This book, which relates the many interests of Edoardo Benvenuto except for his theological concerns, covers a wider subject than the mere between mechanics and architecture, but is still related to it. The work is divided in five parts: Part I: Strength of Materials and Structural Mechanics, inquires the problems of modern construction (resistance to earthquakes) regardless to history, unless when the object or monument which has to be preserved requires it; Part II: History of Applied Mechanics; Part III: Between Mechanics and Architecture. Parts II and III, on the other hand, both include studies that fall into the project “Between Mechanics and Architecture”; Part IV: Dedicated to Edoardo Benvenuto; and Part V: Architecture and History.)
- BECCHI, A., M. CORRADI, F. FOCE, and O. PEDEMONTE, eds. 2003. *Essays on the history of mechanics. In Memory of Clifford Ambrose Truesdell and Edoardo Benvenuto*. Basel: Birkhäuser. (Quoting from the Preface: “In the last twenty years, the works of these authors [Saint-Venant, Todhunter and Pearson, Duhem, Mach, Dugas, Timoshenko, Truesdell, Heyman, Szabó, Charlton, Benvenuto, and Di Pasquale] have led new generations of scholars to delve into themes of research that involve diverse disciplines—from mathematics to construction, from architecture to geometry, from the strength of materials to the mechanics of solids and structures—leading to the formulation of the research project “Between Mechanics and Architecture” (p. 7).)

4.3 Individual papers

We now look at the papers of these five collections which are related to the idea “Between Mechanics and Architecture,” and make a statistical analysis of the various topics (Fig. 6).

4.3.1 Simple machines and ancient building techniques (5 papers)

These papers inquire into lifting machines and the way problems of lifting are solved in buildings whose context is either not at all or only slightly theoretically mechanized.

- LANER, F. 1995. La construction des «Nuraghi» en Sardaigne. Pp. 21-31 in *Between Mechanics and Architecture*, Birkhäuser, Basel. (The Nuraghe is seen as the machine of itself. This paper shows how mechanics may be generated from archaic constructions.)
- GULLINI, G. 1995. The so-called “petrification” and the Birth of the Science of Construction in the Greek Architecture. Pp. 33-46 in *Between Mechanics and Architecture*, Birkhäuser, Basel.

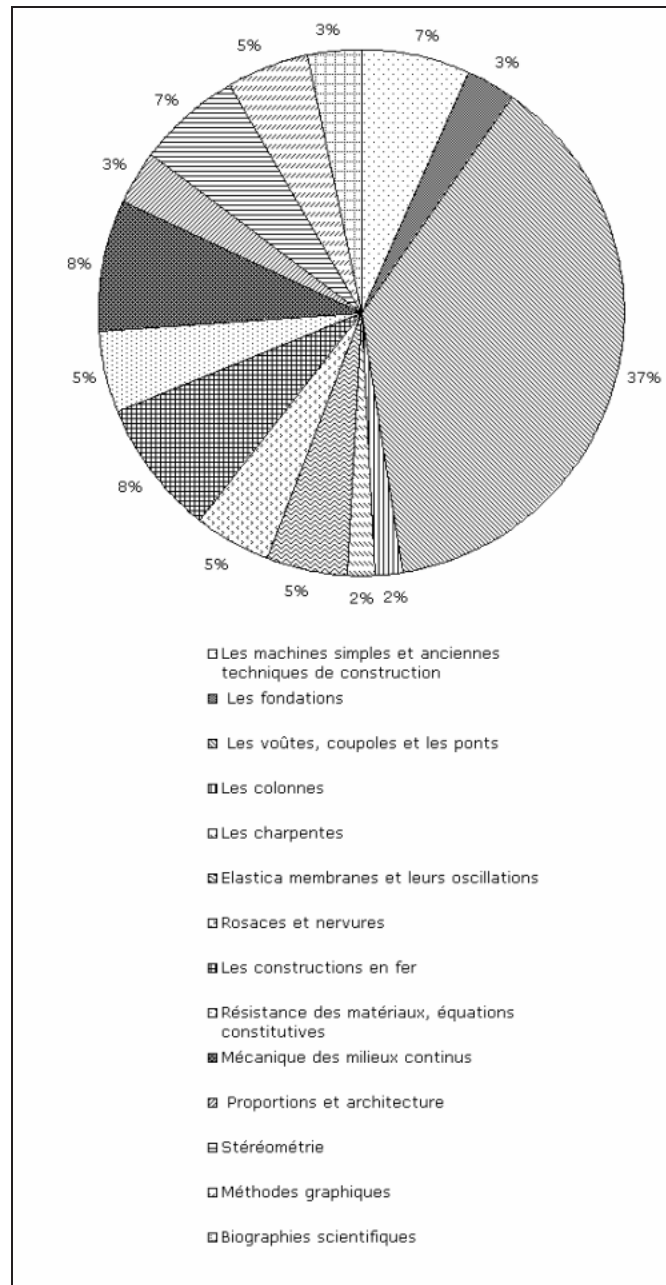


Fig. 6. percentage by topic of the papers of “Between Mechanics and Architecture”

ARISTOTELIS MECHANICA

Græca, emendata, Latina facta, & Com-
mentariis illustrata:

A B

HENRICO MONANTHOLIO
Medico, & Mathematicarum artium
Professore Regio.

A D

HENRICVM III. GALLIÆ & NAVARRÆ
Regem Christianissimum.

Accedit ab eodem autore Tractatus de Puncto.



LVGDVNI B.
Ex Bibliopolio Commeliniano.
ANNO MD. IXX.

Fig. 7. Frontispiece of Aristotle's text on simple machines, edited by Monantheuil

- CAPPAL, S. N. 2003. A hypothesis on a building technique to determine the shape of the nuragic tholoi. Pp. 535-544 in S. HUERTA, ed. *Proceedings of the First International Congress on Construction History*, 3 vols., Instituto Juan de Herrera, Madrid.
- LARDA INARRA, J. and A. MARTINEZ RODRIGUEZ. 2000. Las gruas de Juan de Herrera. Pp. 623-628 in GRACIANI GARCIA, et al., *Actas del Tercer Congreso Nacional de Historia de la Construcción*, 2 vols, CEHOPU.
- IGNACIO VICENS, G. de, M. A. FLOREZ DE LA COLINA, and J. L. J. PEREZ MARTIN. 2000. Medios de elevacion de materiales en la construcción medieval. Pp. 1113-1122 in GRACIANI GARCIA, et al., *Actas del Tercer Congreso Nacional de Historia de la Construcción*, 2 vols, CEHOPU.

4.3.2 Foundations (2 papers)

These papers inquire into ancient problems of stability and earth mechanics.

- GARCIA GAMALLO, A. M. 2003. The evolution of traditional types of building foundation prior to the first industrial revolution. Pp. 943-956 in S. HUERTA, ed. *Proceedings of the First International Congress on Construction History*, 3 vols., Instituto Juan de Herrera, Madrid.
- MENDONÇA DE OLIVEIRA, M. and E. POUSADA PRESA. 2003. Reinforcing foundations with wood piles: origin and historic development. Pp. 1537-1545 in S. HUERTA, ed. *Proceedings of the First International Congress on Construction History*, 3 vols., Instituto Juan de Herrera, Madrid.

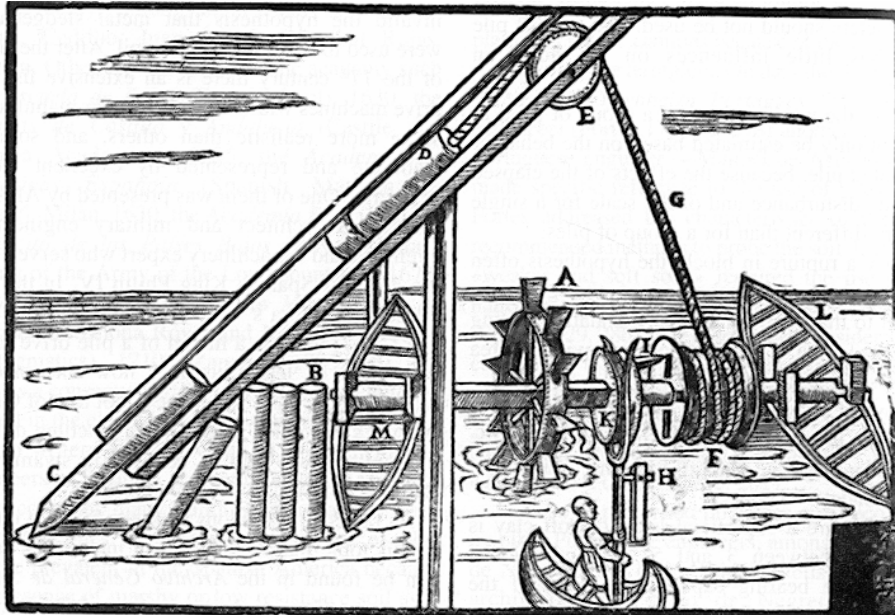


Fig. 8. Piles being driven into water

4.3.3 Vaults, domes and bridges (26 papers)

4.3.3.1 Thin vault, stable from its own weight, and catenary (7 papers)

Without a doubt this is the problem that has led to the most inquiry, probably because this is the very point where mechanics and architecture meet, along with mathematics, since the solutions require differential calculus.

- COPANI, P. and L. BUONANNO. 2003. The “Cuba” near Castiglione in Sicily: a self-supporting vault made of volcanic stone (XIth – XIIth centuries). Pp. 611-621 in S. HUERTA, ed. *Proceedings of the First International Congress on Construction History*, 3 vols., Instituto Juan de Herrera, Madrid.
- TAUPIN, J. L. 2003. The geometer and the cathedral. Pp. 1953-1962 in S. HUERTA, ed. *Proceedings of the First International Congress on Construction History*, 3 vols., Instituto Juan de Herrera, Madrid. This paper is about the catenary of the twelfth-century vault of Chartre and the thirteenth-century Cathedral of Beauvais
- AITA D. AND M. CORRADI. 2003. On the equilibrium of the flat arch with joints that have neither friction nor cohesion. Pp. 505-521 in A. BECCHI, M. CORRADI, F. FOCE, and O. PEDEMONTE, *Towards a history of construction*. Birkhäuser, Basel.
- BECCHI, A. 2003. Before 1695: the statics of arches between France and Italy. Pp. 353-364 in S. HUERTA, ed. *Proceedings of the First International Congress on Construction History*, 3 vols., Instituto Juan de Herrera, Madrid.
- RADELET-DE GRAVE, P. 1995. Le “de curvatura fornicis” de Jacob Bernoulli (1704). Pp. 141-163 in P. RADELET-DE GRAVE and E. BENVENUTO, eds., *Between Mechanics and Architecture*, Birkhäuser, Basel.
- PESCIULLES C. and M. RAPALLINI. 1995. The Analogy between Equilibrium of Threads and Thin Masonry Structures. Pp. 123-139 in P. RADELET-DE GRAVE and E. BENVENUTO, eds., *Between Mechanics and Architecture*, Birkhäuser, Basel.
- TAZZIOLI, R. 1995. Construction engineering and natural philosophy: the work by Gabriel Lamé. Pp. 318-329 in P. RADELET-DE GRAVE and E. BENVENUTO, eds., *Between Mechanics and Architecture*, Birkhäuser, Basel. This paper brings back the analogy between the catenary and the vault as proposed by Lamé.

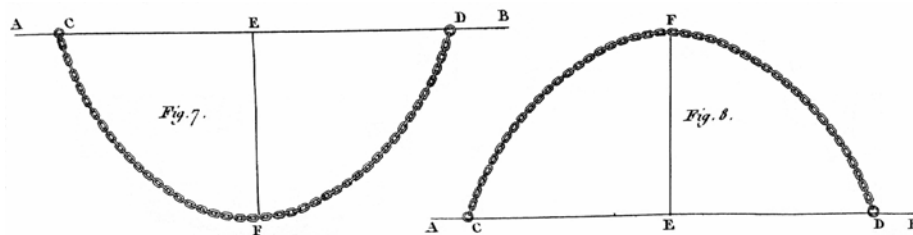


Fig. 9. Arch and catenary by Belidor

4.3.3.2. Other vaults, bridges (5 papers)

- SASSI PERINO, A. M. 1995. Un monument du XIXe siècle à Turin: le Pont Mosca sur la Doire. Pp. 275-287 in P. RADELET-DE GRAVE and E. BENVENUTO, eds., *Between Mechanics and Architecture*, Birkhäuser, Basel.
- RABASA, L. 2003. The single coursed ashlar vault (XVIth – XXth centuries). Pp. 1680-1689 in S. HUERTA, ed. *Proceedings of the First International Congress on Construction History*, 3 vols., Instituto Juan de Herrera, Madrid. (This is an example of a building technique that generates an architectural shape.)
- TAMBORÉRO, L. and J. SAKAROVITCH. 2003. The vault of Arles City Hall: a carpentry outline for a stone vault. Pp. 1899-1907 in S. HUERTA, ed. *Proceedings of the First International Congress on Construction History*, 3 vols., Instituto Juan de Herrera, Madrid.
- HUERTA, S. 2003. The Mechanics of Timbered Vaults: a Historical Outline. Pp. 89-133 in A. BECCHI, M. CORRADI, F. FOCE, and O. PEDEMONTE, eds. *Essays on the history of mechanics. In Memory of Clifford Ambrose Truesdell and Edoardo Benvenuto*, Birkhäuser, Basel.
- HUERTA S. and F. FOCE, 2003. Vault theory in Spain between XVIIIth and XIXth century: Monasterio’s unpublished manuscript “Nueva teorica sobre el empuje de bovedas”. Pp. 1155-1166 in S. HUERTA, ed. *Proceedings of the First International Congress on Construction History*, 3 vols., Instituto Juan de Herrera, Madrid.

4.3.3.3 Domes (3 papers)

- PARADISO, M., RAPALLINI, M. and TEMPESTA, G. 2003. Masonry domes. Comparison between some solutions under no-tension hypothesis). (Pp. 1571-1581 in S. HUERTA, ed. *Proceedings of the First International Congress on Construction History*, 3 vols., Instituto Juan de Herrera, Madrid.
- LOPEZ MANZANARES, G. 2000. La forma ideal de las cupulas: el ensayo de Bouguer (1734). Pp. 604-621 in A. GRACIANI GARCIA, S. HUERTA FERNANDEZ, E. RABASA DIAZ, and M.A. TABALES RODRIGUEZ, eds. *Actas del Tercer Congreso Nacional de Historia de la Construcción*, 2 vols, CEHOPU.
- LOPEZ MANZANARES, G. 2003. The XVIIIth century: Carlo Fontana’s expertises. (Pp. 506-512 in S. HUERTA, ed. *Proceedings of the First International Congress on Construction History*, 3 vols., Instituto Juan de Herrera, Madrid. (On the of construction domes.)

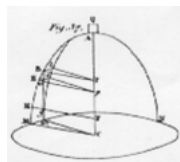


Fig. 10. Dome according to Lorenzo Mascheroni

4.3.3.4 Principles of Mechanics (4 papers)

- RADELET-DE GRAVE, P. 2003. The Use of a Particular Form of the Parallelogram Law of Forces for the Building of Vaults (1650-1750). Pp. 135-163 in A. BECCHI, M. CORRADI, F. FOCE, and O. PEDEMONTE, eds. *Essays on the history of mechanics. In Memory of Clifford Ambrose Truesdell and Edoardo Benvenuto*, Birkhäuser, Basel.
- SINOPOLI, A. 2003. The role of geometry in the theories on vaulted structures by Lorenzo Mascheroni. Pp. 1864-1873 in S. HUERTA, ed. *Proceedings of the First International Congress on Construction History*, 3 vols., Instituto Juan de Herrera, Madrid.
- AGENO, A., FOCE, F., FRILLI, M. 2000. From “empeiria” to calculation in Gauthy’s “Mémoire sur l’application des principes de la mécanique à la construction des voûtes et des dômes”. Pp. 211-224 in A. GRACIANI GARCIA, S. HUERTA FERNANDEZ, E. RABASA DIAZ, and M.A. TABALES RODRIGUEZ, eds. *Actas del Tercer Congreso Nacional de Historia de la Construcción*, 2 vols, CEHOPU.
- GOMEZ DE COZAR, J. C.; RODRIGUEZ LINIAN, C. and PEREZ GALVEZ, P. 2003. Antonio Ramos’s Manuscript. Analysis of a scientific text with an empiric base. Pp. 1043-1050 in S. HUERTA, ed. *Proceedings of the First International Congress on Construction History*, 3 vols., Instituto Juan de Herrera, Madrid, 2003. (Study on forces towards mid XVIth century by Bossut: transmission of forces in a vault.)

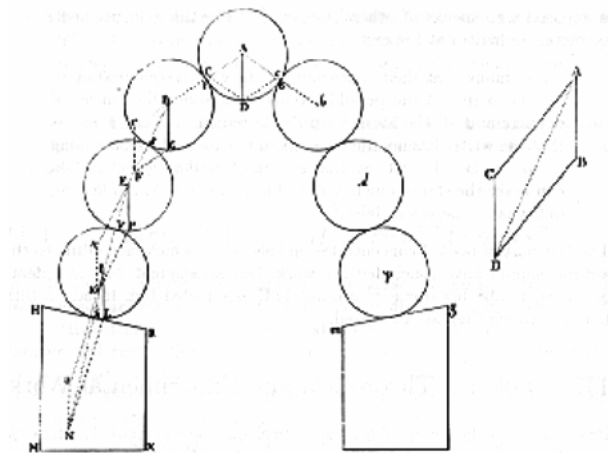


Fig. 11. Figure from Poleni showing forces sliding along the catenary through the gravity centres of the vault stones

4.3.3.5 Structural analysis (4 papers)

- QUAGLIARINI, L., STAZI, A. and M. D’ORAZIO. 2003. Evolution of the analysis criteria for wooden arch structures between the 16th and the 19th century. Pp. 1657-1668 in S. HUERTA, ed. *Proceedings of the First International Congress on Construction History*, 3 vols., Instituto Juan de Herrera, Madrid.

- KURRER, K.-E. 1995. Comment la théorie de l'élasticité s'est imposée à l'analyse de la structure portante des voûtes dans les pays germanophones de 1860 à 1900. Pp. 331-347 in P. RADELET-DE GRAVE and E. BENVENUTO, eds., *Between Mechanics and Architecture*, Birkhäuser, Basel.
- TAZZIOLI, R. 1995. Construction engineering and natural philosophy: the work by Gabriel Lamé. Pp. 331-317 in P. RADELET-DE GRAVE and E. BENVENUTO, eds., *Between Mechanics and Architecture*, Birkhäuser, Basel.). This paper brings back the analogy between the catenary and the vault as proposed by Lamé.
- FOCE, F. and D. AITA. 2003. The masonry arch between “limit” and “elastic” analysis. A critical re-examination of Durand-Claye's method. Pp. 895-908 in S. HUERTA, ed., *Proceedings of the First International Congress on Construction History*, 3 vols., Instituto Juan de Herrera, Madrid.

4.3.3.6 Various (3 papers)

- ABBATE, F. L. BOVE; L. DODARO and M. LIPIELLO. 2003. A peculiar architecture: The open staircase of Naples (XVIIth-XVIIIth centuries). Pp. 91-100 in S. HUERTA, ed., *Proceedings of the First International Congress on Construction History*, 3 vols., Instituto Juan de Herrera, Madrid.
- PETERS, T. F. 2003. Bridge technology and historical scholarship (XVIIIth – XXth centuries). Pp. 61-66 in S. HUERTA, ed., *Proceedings of the First International Congress on Construction History*, 3 vols., Instituto Juan de Herrera, Madrid.
- BUONOPANE, S. G., Spivey, J. M. and Gasparini, D. A. 2003. Engineering analysis as a historical documentation tool: recent work of the Historic American Engineering Record (XIXth century). Pp. 421-442 in S. HUERTA, ed., *Proceedings of the First International Congress on Construction History*, 3 vols., Instituto Juan de Herrera, Madrid.

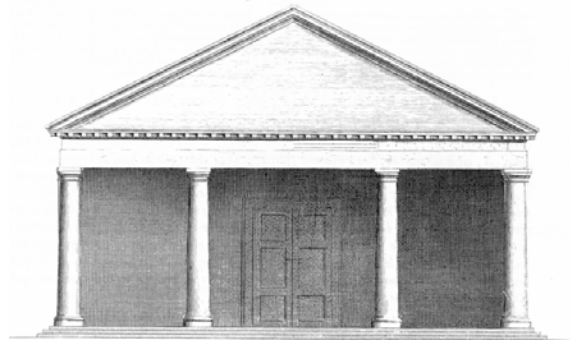


Fig. 12. Columns from the Ten Books of Architecture by Vitruvius, translated by Claude Perrault

4.3.4 Columns (1 paper)

A topic of which Edoardo Benvenuto was particularly fond, but that had not been inquired into at length yet.

EGGEMANN, H. 2003. Development of composite columns. Emperger's effort. Pp. 737-797 in S. HUERTA, ed. *Proceedings of the First International Congress on Construction History*, 3 vols., Instituto Juan de Herrera, Madrid.

4.3.5 Timber frames (1 paper)

CANDELAS GUTIÉRREZ, A. L. 2003. On the origin of some "whiteness" carpentry rules. (Pp. 506-512 in S. HUERTA, ed. *Proceedings of the First International Congress on Construction History*, 3 vols., Instituto Juan de Herrera, Madrid.

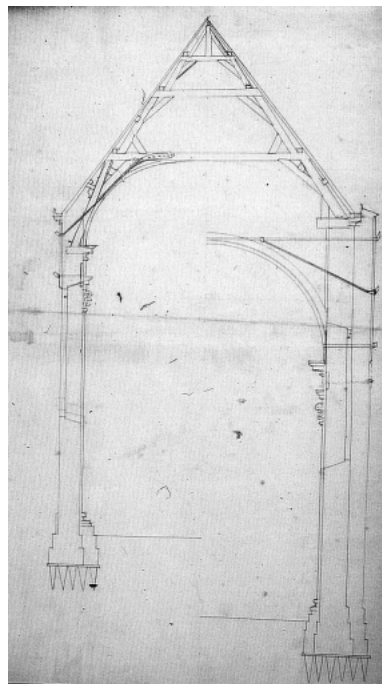


Fig. 13 : Frame from Dolmans's *Promptuarium*, a manuscript from the Jesuit library in Leuven

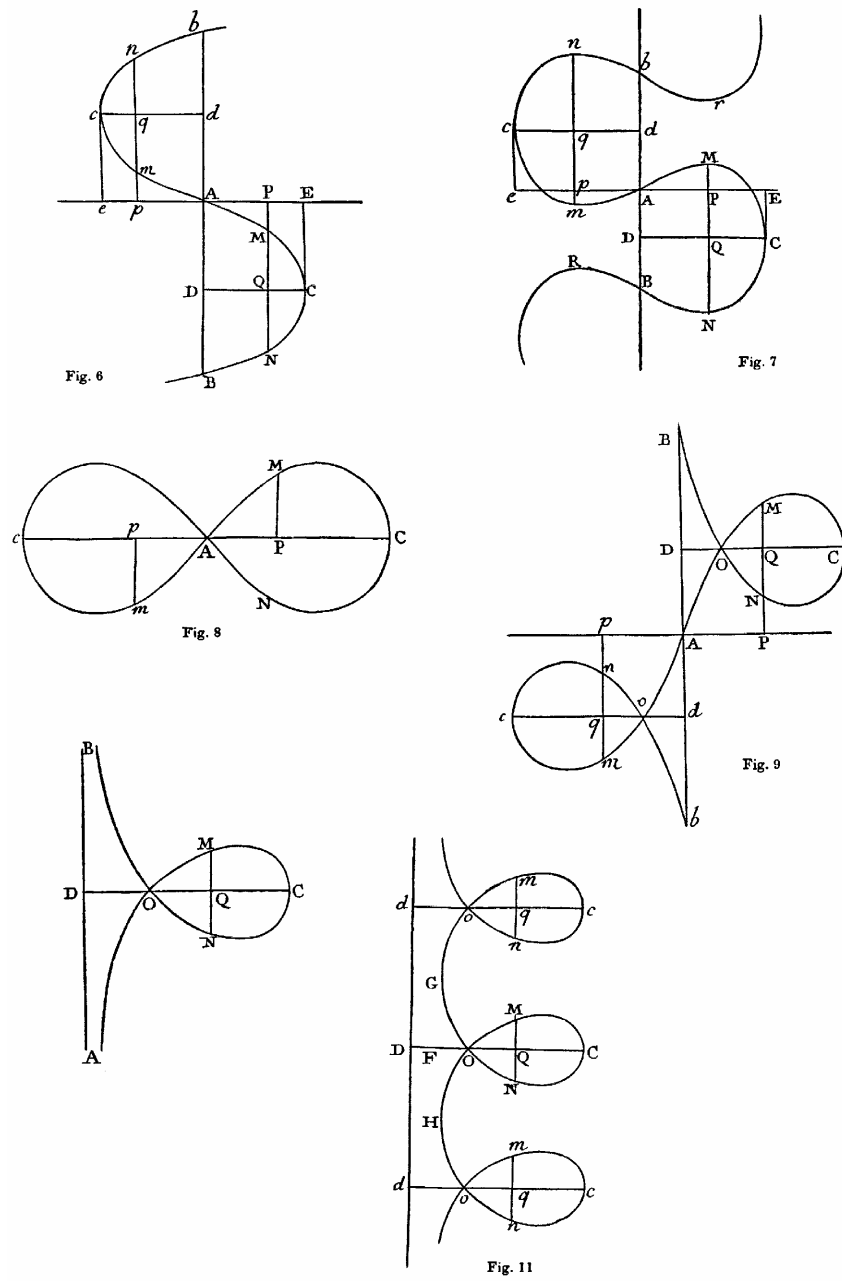


Fig. 14. Elastica's various forms by Euler

4.3.6 Elastica membranes and their oscillations (3 papers)

- ESCRIG, F.; CAMPAN, V.; SANCHEZ, J. and PÉREZ VALCARCEL, J. 2003. Shells and membranes in the architecture of the XVIIIth century. Pp. 817-827 in S. HUERTA, ed. *Proceedings of the First International Congress on Construction History*, 3 vols., Instituto Juan de Herrera, Madrid.
- O' MATHUNA, D. 1995. Jacob II Bernoulli and the Problem of the Vibrating Plate. Pp. 166-177 in P. RADELET-DE GRAVE and E. BENVENUTO, eds., *Between Mechanics and Architecture*, Birkhäuser, Basel.
- PICON, A. 1995. Entre science et art de l'ingénieur. L'enseignement de Navier à l'Ecole des Ponts et Chaussées. Pp. 258-273 in P. RADELET-DE GRAVE and E. BENVENUTO, eds., *Between Mechanics and Architecture*, Birkhäuser, Basel. (This study is about the oscillation of elastic leaf.)

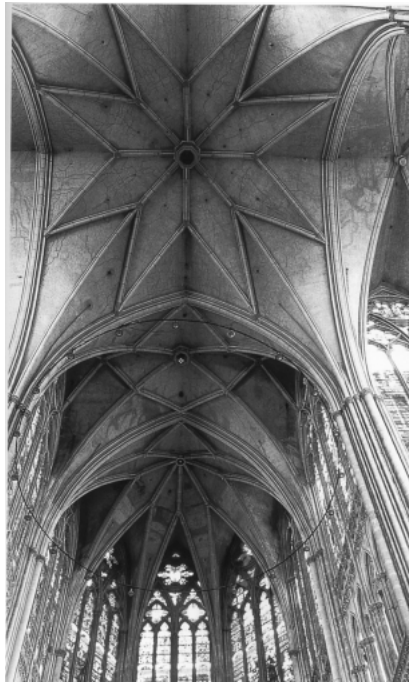


Fig. 15. Ribs and vaulting of the Cathedral of Metz

4.3.7 Rose windows and ribs (3 papers)

The purpose is not so much to study their aesthetic aspect rather than their role in the stability of the structure.

- BARTHEL, R.; SCHIEMANN, L. and JAGFELD, M. 2003. Static analysis and evaluation of the construction system of a Gothic «choir-window» consisting of a fine filigree tracery and slender stone ribs. Pp. 333-340 in S. HUERTA, ed. *Proceedings of the*

First International Congress on Construction History, 3 vols., Instituto Juan de Herrera, Madrid.

Heyman, J. 2003. Rose Windows. Pp. 165-177 in A. BECCHI, M. CORRADI, F. FOCE, and O. PEDEMONTE, eds. *Essays on the history of mechanics. In Memory of Clifford Ambrose Truesdell and Edoardo Benvenuto*, Birkhäuser, Basel.

COSTE, A. 2003. Gothic vaults: a rationalist or a tectonic track for the force of the ribs? (Pp. 657-664 in S. HUERTA, ed. *Proceedings of the First International Congress on Construction History*, 3 vols., Instituto Juan de Herrera, Madrid.

4.3.8 Iron structures (5 papers)

As Edoardo Benvenuto shows in his book *An Introduction to the History of Structural Analysis*, this topic is an important turning point in the history of “Between Mechanics and Architecture.”

RADELET-DE GRAVE, P. 2003. Arthur Vierendeel (1852- 1940). Pour une architecture du fer. Pp. 417-453 in A. BECCHI, M. CORRADI, F. FOCE, and O. PEDEMONTE, *Towards a history of construction*. Birkhäuser, Basel 2003.

SACCHI LANDRIANI, G. 2003. Eiffel et la mécanique. Pp. 475-482 in A. BECCHI, M. CORRADI, F. FOCE, and O. PEDEMONTE, *Towards a history of construction*. Birkhäuser, Basel 2003.

KURRER, K.-E. 2003. De la statique classique des constructions à la statique sur ordinateur. Pp. 263-296 in A. BECCHI, M. CORRADI, F. FOCE, and O. PEDEMONTE, *Towards a history of construction*. Birkhäuser, Basel.

SASSI PERINO, M. 2003. Studies on instability phenomena between the 19th and the 20th century: the conceptual value of the Engesser-Shanley theory. (Pp. 333-340 in A. BECCHI, M. CORRADI, F. FOCE, and O. PEDEMONTE, *Towards a history of construction*. Birkhäuser, Basel.

GASPARINI, D. A. and F. FRANCESCA. 2003. Prestressing of 19th century wood and iron truss bridges in the US. Pp. 977-986 in S. HUERTA, ed. *Proceedings of the First International Congress on Construction History*, 3 vols., Instituto Juan de Herrera, Madrid.

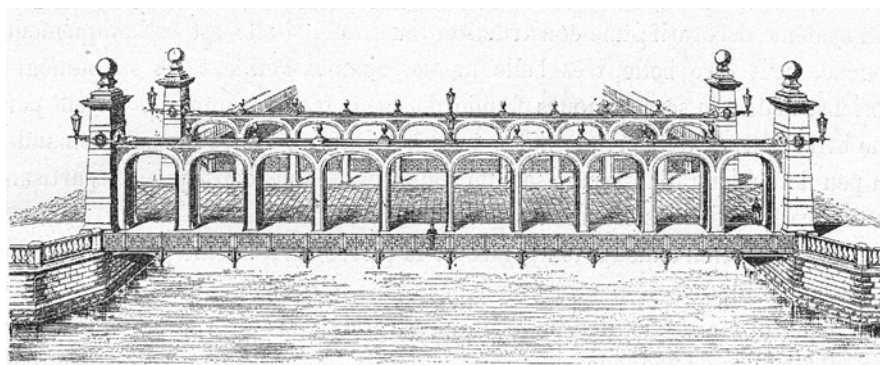


Fig. 16. Iron bridge designed by A. Vierendeel

4.3.8 Strength of materials, component equations (4 papers)

This topic was Truesdell's favourite. It is particularly wide, yet still too rarely inquired, probably because of its difficulty.

- BECCHI, A., 1995. Les conditions de résistance des matériaux entre resistentia solidorum et hydrostéréodynamique. Pp. 289-298 in P. RADELET-DE GRAVE and E. BENVENUTO, eds., *Between Mechanics and Architecture*, Birkhäuser, Basel.
- FOCE, F. 1995. The theory of elasticity between molecular and continuum approach in the XIX Century. Pp. 301-314 in P. RADELET-DE GRAVE and E. BENVENUTO, eds., *Between Mechanics and Architecture*, Birkhäuser, Basel,.
- DI PASQUALE, S. 1995. On the Art of Building before Galilei. Pp. 103-121 in P. RADELET-DE GRAVE and E. BENVENUTO, eds., *Between Mechanics and Architecture*, Birkhäuser, Basel. This paper is about the birth of the strength of materials.
- SIMONNET, C. 2003. Résistance et matériaux. Pp. 483-490 in A. BECCHI, M. CORRADI, F. FOCE, and O. PEDEMONTE, *Towards a history of construction*. Birkhäuser, Basel 2003. Simonnet speaks of the strength of materials at the time when reinforced concrete was invented.

4.3.10 Mechanics of continuous media (5 papers)

In this category we include hydrostatics, hydrodynamics, elasticity and plasticity.



Fig. 17. torsion drawn by Saint-Venant

- CORRADI, M. 1995. De la statique des demi-fluides à la théorie de la poussée des terres. Pp. 221-254 in P. RADELET-DE GRAVE and E. BENVENUTO, eds., *Between Mechanics and Architecture*, Birkhäuser, Basel.

- CORRADI, M. 2003. La mécanique des sols proposée par les élèves de Saint-Venant. Pp. 225-252 in A. BECCHI, M. CORRADI, F. FOCE, and O. PEDEMONTE, *Towards a history of construction*. Birkhäuser, Basel.
- MIKHAILOV, G. 2003. Development of Studies in the History of Elasticity Theory and Structural Mechanics. Pp. 21-37 in A. BECCHI, M. CORRADI, F. FOCE, and O. PEDEMONTE, eds. *Essays on the history of mechanics. In Memory of Clifford Ambrose Truesdell and Edoardo Benvenuto*, Birkhäuser, Basel.
- CORRADI, M. 2003. From the “Architecture hydraulique” to the “Science des ingénieurs”: Hydrostatics and Hydrodynamics in the XIXth century. Pp. 635-644 in S. HUERTA, ed. *Proceedings of the First International Congress on Construction History*, 3 vols., Instituto Juan de Herrera, Madrid.
- Heyman, J. 2003. Truesdell and the History of the Theory of Structures. Pp. 9-19 in A. BECCHI, M. CORRADI, F. FOCE, and O. PEDEMONTE, eds. *Essays on the history of mechanics. In Memory of Clifford Ambrose Truesdell and Edoardo Benvenuto*, Birkhäuser, Basel. (Heyman speaks about the beginning of the studies on plasticity and about hierarchies and dependences in sciences.)

4.3.11 Proportions and architecture (2 papers)

The call for geometry, and more precisely on proportion theory, goes back to Vitruvius. Aristotle and Archimedes apply this theory to mechanics while giving the lever law.

- GIRON SIERRA, J. 2000. De las medias a las progresiones. Los cambios en los sistemas de proporcion inducidos por la Revolucion Cientifica. Pp. 375-387 in A. GRACIANI GARCIA, S. HUERTA FERNANDEZ, E. RABASA DIAZ, and M.A. TABALES RODRIGUEZ, eds. *Actas del Tercer Congreso Nacional de Historia de la Construcción*, 2 vols, CEHOPU.
- NAPOLITANI, P. D. 1995. La géométrisation des qualités physiques au XVIe siècle: les modèles de la théorie des proportions. Pp. 69-86 in P. RADELET-DE GRAVE and E. BENVENUTO, eds., *Between Mechanics and Architecture*, Birkhäuser, Basel.

4.3.12 Stereometry (4 papers)

Perspective and descriptive geometry are among the mathematical developments stimulated by architecture.

- SAKAROVITCH, J. 1995. The Teaching of Stereotomy in Engineering Schools in France in the XVIIIth and XIXth centuries: an Application of Geometry, an “Applied Geometry”, or a Construction Technique? Pp. 205-218 in P. RADELET-DE GRAVE and E. BENVENUTO, eds., *Between Mechanics and Architecture*, Birkhäuser, Basel.
- SAKAROVITCH, J. 2003. Stereotomy, a multifaceted technique. Pp. 69-79 in S. HUERTA, ed. *Proceedings of the First International Congress on Construction History*, 3 vols., Instituto Juan de Herrera, Madrid.
- AITA, D. 2003. Between geometry and mechanics: A re-examination of the principles of stereotomy from a statical point of view. Pp. 161-170 in S. HUERTA, ed. *Proceedings*

of the First International Congress on Construction History, 3 vols., Instituto Juan de Herrera, Madrid.

CALVO LOPEZ, J. 2003. Orthographic projection and true size in Spanish stonecutting manuscripts. Pp. 460-471 in S. HUERTA, ed., *Proceedings of the First International Congress on Construction History*, 3 vols., Instituto Juan de Herrera, Madrid.

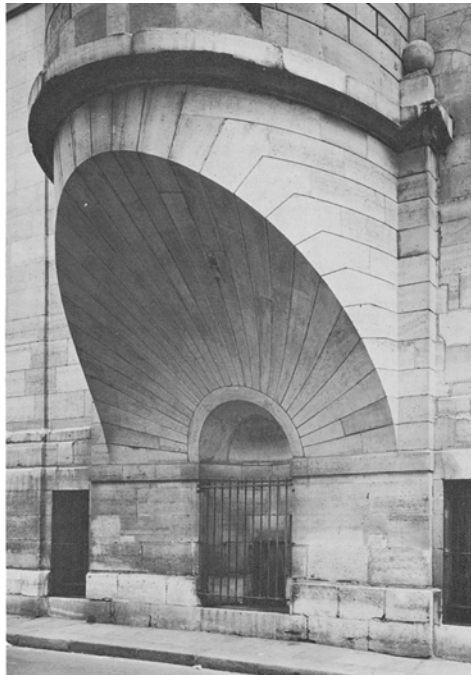


Fig. 18. Exceptional example of stereotomy

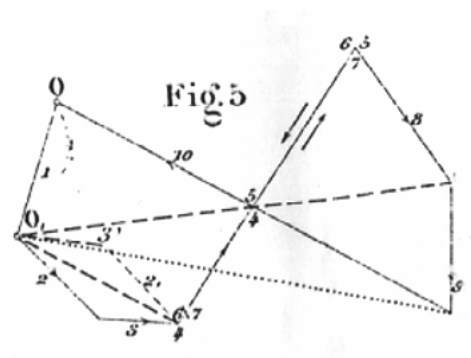


Fig. 19. Figure from Culmann's treaty on graphical statics

4.3.13 Graphic methods (3 papers)

- GERHARDT, R. 2003. Reflections on the application of graphical methods to statical problems. Pp. 377-383 in A. BECCHI, M. CORRADI, F. FOCE, and O. PEDEMONTE, *Towards a history of construction*. Birkhäuser: Basel.
- GERHARDT, R.; KURRER, K.-E. and PICHLER, G. 2003. The methods of graphical statics and their relation to the structural form. (Pp. 997-1006 in S. HUERTA, ed. *Proceedings of the First International Congress on Construction History*, 3 vols., Instituto Juan de Herrera, Madrid.
- MAINSTONE, R. 2003. Reflections on the related histories of construction and design (Pp. 49-60 in S. HUERTA, ed. *Proceedings of the First International Congress on Construction History*, 3 vols., Instituto Juan de Herrera, Madrid.

4.3.14 Deformation method (1 paper)

- KURRER, K.- E. 2003. The Development of the Deformation Method. Pp. 57-86 in A. BECCHI, M. CORRADI, F. FOCE, and O. PEDEMONTE, eds. *Essays on the history of mechanics. In Memory of Clifford Ambrose Truesdell and Edoardo Benvenuto*, Birkhäuser, Basel.

4.3.15 Scientific biographies (3 papers)

- CHATZIS, K. 2003. Mécanique physique, expérimentation et tradition dans la science des constructions de J.- V . Poncelet (1788- 1867). Pp. 343-354 in A. BECCHI, M. CORRADI, F. FOCE, and O. PEDEMONTE, *Towards a history of construction*. Birkhäuser: Basel.
- OCHSENDORF, J. and J. ANTUNA. 2003. Eduardo Torroja and “Ceramica Armada”. Pp. 1528-1536 in S. HUERTA, ed. *Proceedings of the First International Congress on Construction History*, 3 vols. Madrid: Instituto Juan de Herrera.

Conclusion

I hope I have been able to show that there are now several people aware of the essence of this research and willing to pursue it, but we still have to make some progress about the richest aspect that Edoardo Benvenuto transmitted to us: the analysis, by the means of history, of the relationships between a science and an art, or to use his own words in the introduction of *Between Mechanics and Architecture*, “between exact sciences and humanities”.

Translated from the French by Sylvie Duvernoy