

Invited Paper

# Structural Design in the Work of Gaudí

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**Abstract:** The work of Gaudí embraces all the facets of architectural design. The present paper studies the analysis and design of masonry arches, vaults and buildings. It is well known that Gaudí used hanging models and graphical methods as design tools. These methods can be traced back to the end of the 17th Century. In addition, it was not original the use of equilibrated, catenarian forms. What was completely original was the idea of basing all the structural design in considerations of equilibrium. Gaudí also employed unusual geometrical forms for some of his vaults and ruled surfaces, showing a deep structural insight. Finally, he designed tree-forms of equilibrium for the supports of the vaults in the Sagrada Família. In the present paper Gaudí's equilibrium methods are studied with some detail, stressing their validity within the frame of Limit Analysis.

**Keywords:** Structural design; Gaudí; Masonry arches; Vaults; Catenarian forms; Equilibrium methods; Limit analysis

## Introduction

Antoni Gaudí (1852–1926) was a Master Builder. His work covers all aspects of architecture: layout, ornamentation and stability. He also incorporates other arts: sculpture (particularly), painting, and photography. Any study of Gaudí's work must embrace this global concept of the project. This article considers only one of the aspects of Gaudí's work: the design and calculation of structures. For Gaudí, structural design was an integral part of architectural design from its initial stages. It was not restricted, as was the usual case in those days, to a mere stability check. This paper will go through the different structural elements, studying the detail of Gaudí's design and calculation process and attempt to place his activity in a historical context.

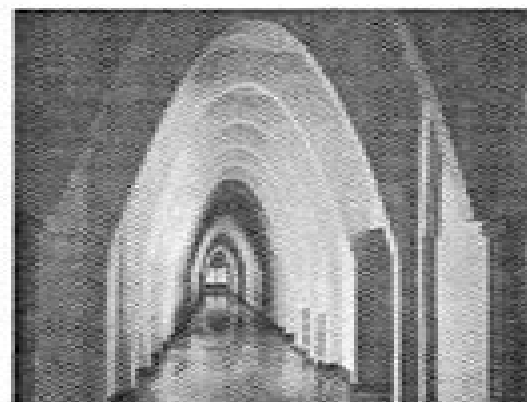
## Catenary Arches

From his first projects, Gaudí showed his originality and independence. In particular, he began to use systematically a type of arch not common in the western architectural tradition. Instead of using arches with a shape derived from

the circle (roman, pointed, basket-handle, etc.), he used arches with non-circular shapes: parabolic or "catenary." These arches are already present in Gaudí's first buildings, seen in Figures 1 and 2.



(a)



(b)

Figure 1. Catenary arches: (a) Entrance to the Palaciu Güell (Rafel 1929); (b) corridor in the School of the Teresianas (Tarragó 1991).

# Nature Of Structural Design And Safety

**Y Pai**



## **Nature Of Structural Design And Safety:**

**The Nature of Structural Design and Safety** D. I. Blockley, 1980      **The nature of structural design and safety, by...** David Ian Blockley, 1980      **The Nature of Structural Design and Safety**, 1980      *The New Engineer* Sharon Beder, 1998      **Optimal Reliability-Based Design of Structures Against Several Natural Hazards** Alfredo H-S Ang, David de Leon Escobedo, Wenliang Fan, 2021-08-10

Interest in the topic of structural reliability and optimal design has been rapidly growing in recent years. Besides the field of numerical methods and artificial intelligence is experiencing a surge of new methods and the refinement of existing ones to expand opportunities to apply robust formulations to complex engineering problems. Today more than ever the field is receiving fresh ideas on how to face the challenges of finding a balance between cost and benefits that may lead towards the optimal design of systems. Recently the probability density evolution method PDEM was proposed by Prof Jie Li as an alternative way to obtain the stochastic and dynamic solution of the safety level of engineering systems under any kind of hazard. This work deals with the application of this powerful method to derive optimal design recommendations for large engineering systems under natural hazards. The three case studies illustrate to engineers and academic specialists how to strike a cost effective balance in designing such systems.      *NIST Special Publication*, 1988      *Rock Mechanics for Natural Resources and Infrastructure Development - Full Papers* Sergio A.B. Fontoura, Ricardo Rocca, José Mendoza, 2019-09-03

Rock Mechanics for Natural Resources and Infrastructure Development contains the proceedings of the 14th ISRM International Congress ISRM 2019 Foz do Iguaçu Brazil 13-19 September 2019. Starting in 1966 in Lisbon Portugal the International Society for Rock Mechanics and Rock Engineering ISRM holds its Congress every four years. At this 14th occasion the Congress brings together researchers, professors, engineers and students around contemporary themes relevant to rock mechanics and rock engineering. Rock Mechanics for Natural Resources and Infrastructure Development contains 7 Keynote Lectures and 449 papers in ten chapters covering topics ranging from fundamental research in rock mechanics laboratory and experimental field studies and petroleum mining and civil engineering applications. Also included are the prestigious ISRM Award Lectures: the Leopold Muller Award Lecture by professor Peter K. Kaiser and the Manuel Rocha Award Lecture by Dr Quinghua Lei. Rock Mechanics for Natural Resources and Infrastructure Development is a must read for academics, engineers and students involved in rock mechanics and engineering. Proceedings in Earth and Geosciences Volume 6. The Proceedings in Earth and Geosciences series contains proceedings of peer reviewed international conferences dealing in earth and geosciences. The main topics covered by the series include geotechnical engineering, underground construction, mining, rock mechanics, soil mechanics and hydrogeology.

**A Century of Excellence in Measurements, Standards, and Technology** David R. Lide, 2018-02-06. Established by Congress in 1901, the National Bureau of Standards (NBS) is now the National Institute of Standards and Technology (NIST). NIST has a long and distinguished history as the custodian and disseminator of the United States standards of physical measurement.

Having reached its centennial anniversary the NBS NIST reflects on and celebrates its first century with this book describing some of its seminal contributions to science and technology Within these pages are 102 vignettes that describe some of the Institute s classic publications Each vignette relates the context in which the publication appeared its impact on science technology and the general public and brief details about the lives and work of the authors The groundbreaking works depicted include A breakthrough paper on laser cooling of atoms below the Doppler limit which led to the award of the 1997 Nobel Prize for Physics to William D Phillips The official report on the development of the radio proximity fuse one of the most important new weapons of World War II The 1932 paper reporting the discovery of deuterium in experiments that led to Harold Urey s1934 Nobel Prize for Chemistry A review of the development of the SEAC the first digital computer to employ stored programs and the first to process images in digital form The first paper demonstrating that parity is not conserved in nuclear physics a result that shattered a fundamental concept of theoretical physics and led to a Nobel Prize for T D Lee and C Y Yang Observation of Bose Einstein Condensation in a Dilute Atomic Vapor a 1995 paper that has already opened vast new areas of research A landmark contribution to the field of protein crystallography by Wlodawer and coworkers on the use of joint x ray and neutron diffraction to determine the structure of proteins

**Extreme Man-Made and Natural Hazards in Dynamics of Structures** Adnan Ibrahimbegovic,Ivica Kozar,2007-05-16 This book provides a critical assessment of current knowledge and indicates new challenges which are brought about at present times by fighting man made and natural hazards in transient analysis of structures The latter concerns both permanently fixed structures such as those built to protect people and or sensitive storage material or special structures like bridges and tunnels and moving structures such as trains planes ships or cars

**Natural Disasters** P. A. Merriman,C. W. A. Browitt,1993 It has been estimated that as a result of natural disasters during the 1970s and 1980s three million lives were lost worldwide the number of disasters increased threefold the economic losses per decade almost doubled and the insurance losses quadrupled In the light of these figures the United Nations proclaimed the 1990s as the International Decade for Natural Disaster Reduction and this book focuses on the British contribution to the Decade and is supplemented by papers from America Asia Europe and Africa

**Safety at Natural-gasoline Plants** G. B. Shea,1929 **Human-Computer Interaction. Multimodal and Natural Interaction**

Masaaki Kurosu,2020-07-10 The three volume set LNCS 12181 12182 and 12183 constitutes the refereed proceedings of the Human Computer Interaction thematic area of the 22nd International Conference on Human Computer Interaction HCII 2020 which took place in Copenhagen Denmark in July 2020 A total of 1439 papers and 238 posters have been accepted for publication in the HCII 2020 proceedings from a total of 6326 submissions The 145 papers included in these HCI 2020 proceedings were organized in topical sections as follows Part I design theory methods and practice in HCI understanding users usability user experience and quality and images visualization and aesthetics in HCI Part II gesture based interaction speech voice conversation and emotions multimodal interaction and human robot interaction Part III HCI for well being and

Eudaimonia learning culture and creativity human values ethics transparency and trust and HCI in complex environments

The conference was held virtually due to the COVID 19 pandemic      **Civil and Environmental Engineering: Concepts, Methodologies, Tools, and Applications** Management Association, Information Resources,2016-01-31 Civil and environmental engineers work together to develop build and maintain the man made and natural environments that make up the infrastructures and ecosystems in which we live and thrive Civil and Environmental Engineering Concepts Methodologies Tools and Applications is a comprehensive multi volume publication showcasing the best research on topics pertaining to road design building maintenance and construction transportation earthquake engineering waste and pollution management and water resources management and engineering Through its broad and extensive coverage on a variety of crucial concepts in the field of civil engineering and its subfield of environmental engineering this multi volume work is an essential addition to the library collections of academic and government institutions and appropriately meets the research needs of engineers environmental specialists researchers and graduate level students      **The Transportation of Alaskan Natural Gas** United States. Congress. Senate. Committee on Interior and Insular Affairs,1976      **Data Center Handbook** Hwaiyu Geng,2014-12-22 Provides the fundamentals technologies and best practices in designing constructing and managing mission critical energy efficient data centers Organizations in need of high speed connectivity and nonstop systems operations depend upon data centers for a range of deployment solutions A data center is a facility used to house computer systems and associated components such as telecommunications and storage systems It generally includes multiple power sources redundant data communications connections environmental controls e g air conditioning fire suppression and security devices With contributions from an international list of experts The Data Center Handbook instructs readers to Prepare strategic plan that includes location plan site selection roadmap and capacity planning Design and build green data centers with mission critical and energy efficient infrastructure Apply best practices to reduce energy consumption and carbon emissions Apply IT technologies such as cloud and virtualization Manage data centers in order to sustain operations with minimum costs Prepare and practice disaster recovery and business continuity plan The book imparts essential knowledge needed to implement data center design and construction apply IT technologies and continually improve data center operations      *Earthquake Engineering Research Center Library Printed Catalog* University of California, Berkeley. Earthquake Engineering Research Center. Library,1975      *Geography of Natural Hazards and Disaster Management* Mr. Rohit Manglik,2024-05-24 Examines natural disasters such as earthquakes floods and cyclones focusing on risk assessment vulnerability analysis and sustainable disaster management      [Life-Cycle of Structures and Infrastructure Systems](#) Fabio Biondini,Dan M. Frangopol,2023-06-28 Life Cycle of Structures and Infrastructure Systems collects the lectures and papers presented at IALCCE 2023 The Eighth International Symposium on Life Cycle Civil Engineering held at Politecnico di Milano Milan Italy 2 6 July 2023 This Open Access Book contains the full papers of 514 contributions including the Fazlur R Khan

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