



Teaching Guide

Teaching Guide				
Identifying Data			2020/21	
Subject (*)	Structural Analysis of Historical Buildings		Code	630567118
Study programme	Mestrado Universitario en Rehabilitación Arquitectónica (Plan 2016)			
Descriptors				
Cycle	Period	Year	Type	Credits
Official Master's Degree	2nd four-month period	First	Optional	3
Language	Spanish			
Teaching method	Face-to-face			
Prerequisites				
Department	Construcións e Estruturas Arquitectónicas, Cívís e AeronáuticasEnxeñaría Civil			
Coordinador	Martín Gutiérrez, Emilio	E-mail	emilio.martin@udc.es	
Lecturers	Martín Gutiérrez, Emilio	E-mail	emilio.martin@udc.es	
Web	moodle.udc.es			
General description	The focus of the subject is oriented to the practical application of numerical methods in stability and structural behavior studies related to buildings with historical value and rehabilitation works in general. Thus useful instrumental skills are developed in expert work or when comparatively assessing the incidence of different intervention alternatives.			
Contingency plan	A single contingency plan is formulated, foreseen for possible situations in which the health context, the limitation of the capacity of academic spaces or other causes lead to a transition either to hybrid teaching or to a scenario of total non-attendance. 1 MODIFICATION OF CONTENTS No changes will be made at this point. 2 METHODOLOGIES MAINTAINING TEACHING METHODOLOGIES All those included in the original writing of the guide: master session, workshop, problem solving and supervised work. TEACHING METHODOLOGIES THAT ARE CHANGED No modification is contemplated, understanding that the planned methodologies will be developed online. 3 MECHANISMS OF PERSONALIZED ATTENTION TO STUDENTS Moodle will host a specific virtual forum through which students can ask questions and interact. Teachers will respond to possible queries either in the forum itself or during the online sessions that are scheduled. Teams will also be used for the purpose of establishing individualized and/or group communication channels, in order to answer questions and analyze the progression of supervised work. 4 MODIFICATIONS IN THE EVALUATION There is no change in the evaluation criteria, as it is asynchronous. As an exception, and in view of the possible difficulties that the students may face, the requirement of minimum attendance may be replaced, at the student's request, by a digital portfolio that facilitates the monitoring of their work. 5 OBSERVATIONS OF THE BIBLIOGRAPHY OR WEBGRAPHY No changes will be made at this point.			

Study programme competences

Code	Study programme competences
A5	E05 - Aptitude ou capacidade para a conservación da obra pesada, mediante a inspección, a análise, o control de calidade, a definición das condicións de mantemento e a estimación da seguridade das estruturas de edificación, incluídas as súas posibles cimentacións, podendo igualmente afrontar a redacción de proxectos de reparación e reforzo, e a dirección da execución asociada.



A8	E08 - Aptitude ou capacidade para redactar informes técnicos e proxectos de rehabilitación do patrimonio edificado, incluídas actividades de asesoramento e consultoría.
B1	CB6 - Posuír e comprender coñecementos que proporcionen unha base ou oportunidade para ser orixinais no desenvolvemento e/ou a aplicación de ideas, a miúdo nun contexto de investigación.
B2	CB7 - Que os estudantes saiban aplicar os coñecementos adquiridos e a súa capacidade de resolución de problemas en contornos novos ou pouco coñecidos dentro de contextos máis amplos (ou multidisciplinares) relacionados coa súa área de estudo.
B4	CB9 - Que os estudantes saiban comunicar as súas conclusións e os coñecementos e as razóns últimas que as sustentan a públicos especializados e non especializados dun modo claro e sen ambigüidades.
C1	T01 - Capacidade de análise e síntese
C4	T04 - Coñecementos de informática relativos ao ámbito de estudo
C5	T05 - Capacidade para a xestión da información
C6	T06 - Resolución de problemas
C12	T12 - Comprensión numérica
C13	T13 - Intuición mecánica

Learning outcomes			
Learning outcomes		Study programme competences	
Acquire generic knowledge of instrumental techniques for auscultation and monitoring of historical constructions.		AJ5 AJ8	
Deepen the study of the mechanical behaviour of the masonry work and the models that allow its analytical characterization to be addressed.		AJ5 AJ8	
Propose an approach to the structural diagnosis techniques of buildings with historical value and rehabilitation works in general, using computer applications based on the programming of numerical methods.		AJ5 AJ8	BJ1 BJ2 CJ4 CJ6 CJ12 CJ13
Become familiar with the use of tools that facilitate the tasks of inspection and technical control, and that can be used to analyze the repercussions to be taken into account when faced with a specific intervention.		AJ5 AJ8	BJ1 BJ2 CJ4 CJ6 CJ12 CJ13
Encourage the development of autonomous attitudinal capacities: a tendency to continuous learning, ability to solve problems effectively, capacities for analysis and synthesis, organization and personal planning, productive management of documentation, and use of information and communication technologies.			BJ4 CJ1 CJ5

Contents	
Topic	Sub-topic
Principles, techniques and tools for data collection.	
Complementarity of instrumental and analytical techniques.	
Mechanical behaviour of the masonry work.	
Numerical simulation techniques.	

Planning				
Methodologies / tests	Competencies	Ordinary class hours	Student's personal work hours	Total hours
Guest lecture / keynote speech	A5 B1 B2	12	12	24
Workshop	A5 B1 B2 C4 C6 C12 C13	9	13.5	22.5
Problem solving	A5 B1 B2 C4 C6 C12 C13	0	5	5



Supervised projects	A5 A8 B1 B2 B4 C1 C4 C5 C6 C12 C13	0	22.5	22.5
Personalized attention		1	0	1
(*)The information in the planning table is for guidance only and does not take into account the heterogeneity of the students.				

Methodologies	
Methodologies	Description
Guest lecture / keynote speech	An exhibition methodology complemented by audiovisual means is applied in order to significantly illustrate the contents treated and to facilitate their understanding. However, and independently of the above, during these sessions the aim is to achieve a certain quota of participation by the students, enhancing their involvement, promoting feedback on the process (and therefore the two-way nature of communication), and energizing the learning mechanisms through interaction techniques.
Workshop	The exercise is proposed through guided practices developed with computer means. It contemplates the acquisition of an operational methodology based on practical assumptions with an increasing level of complexity.
Problem solving	Practical tests are proposed, in which specific problematic situations have to be faced, designed from the previously worked content.
Supervised projects	The teaching methodology is basically oriented according to the criterion of learning in action, in order to enhance the acquisition of specific skills. In this context, the elaboration of a comprehensive work takes center stage, where the professional skills of the subject come together, therefore linked to the use of numerical analysis applications, with others of a transversal nature, such as, among others, the search for documentation (often making use of new technologies), the organization and planning of activities, the management of information, or oral and written expression. Schematically, the following steps are distinguished: topic selection, preparation of a generic work script, on-site examination, photographic report, planimetric survey, location and consultation of reference sources, construction and adjustment of models, interpretation of results, and writing a final report that covers the entire work. Given the supervised nature of the same, regular follow-up sessions must be held with the teaching staff, in order to optimize or, where appropriate, redirect the activities in progress.

Personalized attention	
Methodologies	Description
Supervised projects	Given the specificity of the contents linked to the subject, and the different level of computer training with which students can access it, it is understood to be crucial to articulate personalized attention mechanisms that attend to possible singularities. To this end, the development of face-to-face tutorials and consultations through the resources of the virtual platform is used.

Assessment			
Methodologies	Competencies	Description	Qualification
Supervised projects	A5 A8 B1 B2 B4 C1 C4 C5 C6 C12 C13	Its development is fully understood individually and of a non-presential nature. In order to guarantee the authorship of the work, and the adequate acquisition of competences, in its evaluation the successive control sessions are considered relevant, and therefore the degree of compliance in relation to the indications formulated in each case by the teaching staff. Other aspects to assess are: the depth and rigor of development; the search for information sources; the relationships built between the different sections; analysis and synthesis capabilities; the correction of the methodological study, the constructive and structural diagnosis, the modeling and the appropriate conclusions; argumentation; and the grammatical, graphic and technical quality of the final documentation.	100



Assessment comments

As in the other subjects that make up this postgraduate degree, attendance is also required not less than 80% relative to all the scheduled face-to-face sessions. This requirement will have no effect with students who have recognized part-time dedication according to the Norm that regulates the regime of dedication to study and the permanence and progression of undergraduate and master's students at the UDC.

Sources of information

Basic	Hendry, A.W, 1998. Structural Masonry. Macmillan. León, J., 2000. Planteamiento del análisis estructural. Identificación de modos de fallo y criterios de decisión. Lombillo, I., Villegas, L., Silió, D., Hoppe, C., 2008. Evaluación no destructiva del patrimonio construido. Revista Internacional Construlink 16, 40-53. Macchi, G., 1992. Diagnósis estructural y rehabilitación de edificios históricos, Cuadernos INTEMAC. INTEMAC, Madrid. Martínez, J.L., Martín-Caro, J.A., León, J., 2001. Comportamiento mecánico de la obra de fábrica, Monografías sobre el análisis estructural de construcciones históricas de fábrica. Universidad Politécnica de Madrid, Madrid. Schuller, M.P., 20003. Nondestructive testing and damage assessment of masonry structures. Prog. Struct. Engng Mater. 5, 239-251. doi:10.1002/pse.160 Vázquez M., López, E., 2001. El método de los elementos finitos aplicado al análisis estructural. Noela, Madrid. Bibliografía
--------------	---



Complementary

A. Zucchini, Lourenco, P.B, 2007. Mechanics of masonry in compression: Results from a homogenisation approach. *Computers & Structures* 85, 193-204. doi:10.1016/j.compstruc.2006.08.054

Alawadhi, E.M, 2010. Finite element simulations using Ansys. CRC Press, Boca Raton.

Álvarez de Buergo, M., González, T., 1994. Restauración de edificios monumentales: estudio de materiales y técnicas instrumentales. Centro de Estudios y Experimentación de Obras Públicas, Madrid.

Anzani, A, L. Binda, Mirabella, G., 2000. The effect of heavy persistent actions into the behaviour of ancient masonry. *Materials and Structures* 33, 251-261. doi:10.1007/BF02479335

Arede, A., Costa, A., 2002. Inspeção e Diagnóstico Estrutural de Construções Históricas. Algumas contribuições da FEUP. Presented at the 1o Seminário "A Intervenção no Património. Práticas de Conservação e Reabilitação."

Asteris, P.G, 2008. On the structural analysis and seismic protection of historical masonry structures. *The Open Construction and Building Technology Journal* 2, 124-133.

Astudillo, R., García, P., 1995. El ensayo de gato plano como técnica para la auscultación in-situ de obras de fábrica. *Ingeniería Civil* 98, 25-33.

Atamturktur, S., Hemez, F., Cetin, U., 2010. Calibration under uncertainty for finite element models of masonry monuments (No. LA-14414, 974684).

Ballivy, B., Perret, S., Rhazi, J., Palardy, D., Laporte, R., Gagnon, E., n.d. Rehabilitation of hydraulic masonry heritage structures. Injection of special cement-based grouts and tomographic control. *Transactions on the Built Environment* 55.

Barbero, E., 2008. Finite element analysis of composite materials. CRC Press, Boca Raton.

Barros, J.O, Lourenco, P.B, 2000. Size effect on masonry subjected to out-of-plane loading. Presented at the 12th International Brick Masonry Conference, Madrid.

Beconcini, M.L, Bennati, S., Salvatore, W., 2001. Structural characterisation of a medieval bell tower. First historical, experimental and numerical investigations. Presented at the Historical constructions 2001: possibilities of numerical and experimental techniques, Guimarães, pp. 431-444.

Betti, M., Galano, L, 2012. Seismic Analysis of Historic Masonry Buildings: The Vicarious Palace in Pescia (Italy). *Buildings* 2, 63-82. doi:10.3390/buildings2020063

Binda, L., Baronio, G., Palma, M., Penazzi, D., n.d. Il patrimonio storico architettonico ed il terremoto: la diagnosi e gli interventi di recupero. Località di roccanolfi di preci e montesanto di sellano: redazione di schede per il rilievo tipológico e dei danni sismici agli edifici.

Binda, L., Cantini, L., Fernandes, F., Saisi, A., Tedeschi, C., Zanzi, L., 2004. Diagnostic investigation on the historical masonry structures of a castle by the complementary use of non destructive techniques. Presented at the 13 th International Brick and Block Masonry Conference, Amsterdam.

Binda, L., Cardani, G., Saisi, A., Valluzzi, M.R, 2006. Vulnerability analysis of the historical buildings in seismic area by a multilevel approach. *Asian Journal of Civil Engineering (Building and Housing)* 7, 343-357.

Binda, L., Modena, C., Baronio, G., Abbaneo, S., 1997. Repair and investigation techniques for stone masonry walls. *Construction and Building Materials* 11, 133-142. doi:10.1016/S0950-0618(97)00031-7

Binda, L., Saisi, A., 2009. Application of NDTs to the diagnosis of Historic Structures. Presented at the NDTCE'09, Non-Destructive Testing in Civil Engineering, Nantes, France.

Binda, L., Saisi, A., 2005. Research on historic structures in seismic areas in Italy. *Prog. Struct. Engng Mater.* 7, 71-85. doi:10.1002/pse.194

Binda, L., Saisi, A., 2004. Il ruolo delle indagini nella diagnostica strutturale.

Binda, L., Saisi, A., 2001a. Mechanical damage due to long term behaviour of multiple leaf pillars in Sicilian Churches. Presented at the Historical constructions 2001: possibilities of numerical and experimental techniques, Guimarães, pp. 707-718.

Binda, L., Saisi, A., 2001b. Non destructive testing applied to historic buildings. The case of some Sicilian Churches. Presented at the Historical constructions 2001: possibilities of numerical and experimental techniques, Guimarães, pp. 29-46.

Binda, L., Saisi, A., 2001c. State of the art of research on historic structures in Italy.

Binda, L., Saisi, A., Tiraboschi, C., 2001. Application of sonic tests to the diagnosis of damaged and repaired structures. *NDT & E International* 34, 123-138. doi:10.1016/S0963-8695(00)00037-2

Binda, L., Saisi, A., Tiraboschi, C., 2000a. Investigation procedures for the diagnosis of historic masonries. *Construction and Building Materials* 14, 199-233. doi:10.1016/S0950-0618(00)00018-0

Binda, L., Saisi, A., Zanzi, L., 2003. Sonic tomography and flat-jack tests as complementary investigation procedures for the stone pillars of the temple of S. Nicolò l'Arena (Italy). *NDT & E International* 36, 215-227. doi:10.1016/S0963-8695(02)00066-X

Binda, L., Tongini, R., Mirabella, G., 2000b. Survey and investigation for the diagnosis of damaged masonry structures. The Torrazo of Cremona. Presented at the 12th International brick/block masonry conference, University of Madrid, Madrid, pp. 237-257.

Bosilijkov, V., Totoev, Y.Z, Nichols, J.M, 2005. Shear modulus and stiffness of brickwork masonry. An experimental perspective. *Structural Engineering and Mechanics* 20, 21-43. doi:10.12989/sem.2005.20.1.021

Brebbia, C.A, Domínguez, J., Escrig, F., International Conference on Structural Repair and Maintenance of Historical Building (Eds.), 1991. Structural repair and maintenance of historical buildings II. Computational Mechanics Publications, Southampton [etc.].

Brebbia, C.A, Frewier, R.J.B, International Conference on Structural Repair and Maintenance of



Historical Building (Eds.), 1993. Structural repair and maintenance of historical buildings III. Computational Mechanics Publications, Southampton; Boston. Brebbia, C.A, International Conference on Structural Repair and Maintenance of Historical Building (Eds.), 1989. Structural repair and maintenance of historical buildings I. Computational Mechanics, Southampton. Brebbia, C.A, International Conference on Structural Studies, Repairs and Maintenance of Heritage Architecture (Eds.), 2015. Structural studies, repairs and maintenance of heritage architecture XIV. Wit Pr/Computational Mechanics. Brebbia, C.A, International Conference on Structural Studies, Repairs and Maintenance of Heritage Architecture (Eds.), 2013. Structural studies, repairs and maintenance of heritage architecture XIII. Brebbia, C.A, International Conference on Structural Studies, Repairs and Maintenance of Heritage Architecture (Eds.), 2011. Structural studies, repairs and maintenance of heritage architecture XII. WIT Press, Southampton; Boston. Brebbia, C.A, International Conference on Structural Studies, Repairs and Maintenance of Heritage Architecture (Eds.), 2009. Structural studies, repairs and maintenance of heritage architecture XI. WIT, Southampton. Brebbia, C.A, International Conference on Structural Studies, Repairs and Maintenance of Heritage Architecture (Eds.), 2007. Structural studies, repairs and maintenance of heritage architecture X. WIT, Southampton. Brebbia, C.A, International Conference on Structural Studies, Repairs and Maintenance of Heritage Architecture (Eds.), 2005. Structural studies, repairs and maintenance of heritage architecture IX. WIT, Southampton; Boston. Brebbia, C.A, International Conference on Structural Studies, Repairs and Maintenance of Heritage Architecture (Eds.), 2003. Structural studies, repairs and maintenance of heritage architecture VIII. WIT, Southampton. Brebbia, C.A, International Conference on Structural Studies, Repairs and Maintenance of Heritage Architecture (Eds.), 2001. Structural studies, repairs, and maintenance of historical buildings VII. WIT Press, Southampton, UK; Boston. Brebbia, C.A, Jäger, W., International Conference on Structural Studies, Repairs and Maintenance of Heritage Architecture (Eds.), 1999. Structural studies, repairs and maintenance of historical buildings VI. WIT, Southampton; Boston. Brebbia, C.A, Leftheris, B., International Conference on Structural Repair and Maintenance of Historical Building (Eds.), 1995. Structural studies, repairs and maintenance of historical buildings IV. Computational Mechanics. Brignola, A., Frumento, S., Lagomarsino, S., Podestà, S., 2008. Identification of Shear Parameters of Masonry Panels Through the In-Situ Diagonal Compression Test. International Journal of Architectural Heritage 3, 527-73. doi:10.1080/15583050802138634 Buyukozturk, O, NDTMS (Symposium) (Eds.), 2013. Nondestructive testing of materials and structures. Springer, Dordrecht; New York. Calabresi, G., Fattorini, M., 2003. Safety assessment of the foundations of the Basilica of Maxentius in Rome. Transactions on the Built Environment 66. Cámara, L., Latorre, P., 2003. El Modelo Analítico Tridimensional obtenido por fotogrametría. Descomposición, manipulación y aplicaciones en el campo de la restauración arquitectónica. Arqueología de la Arquitectura 2, 87-96. Carpinteri, A., Invernizzi, S., Lacidogna, G., 2009. Historical brick-masonry subjected to double flat-jack test: Acoustic emissions and scale effects on cracking density. Construction and Building Materials 23, 2813-2820. doi:10.1016/j.conbuildmat.2009.03.003 Carpinteri, A., Invernizzi, S., Lacidogna, G., 2007. Structural assessment of a 17th-century masonry vault with acoustic emissions and numerical techniques. International Journal of Architectural Heritage 1, 214-226. doi:10.1080/15583050701287649 Carpinteri, A., Invernizzi, S., Lacidogna, G., 2005. In situ damage assessment and nonlinear modelling of a historical masonry tower. Engineering Structures 27, 387-395. doi:10.1016/j.engstruct.2004.11.001 Carpinteri, A., Lacidogna, G., 2007. Damage evaluation of three masonry towers by acoustic emission. Engineering Structures 29, 1569-1579. doi:10.1016/j.engstruct.2006.08.008 Castellazzi, G., D'Altri, A., Bitelli, G., Selvaggi, I., Lambertini, A., 2015. From laser scanning to finite element analysis of complex buildings by using a semi-automatic procedure. Sensors 15, 18360-18380. doi:10.3390/s150818360 Castro, A., 1999. Historia de la construcción arquitectónica. Edicions UPC, [Barcelona]. Castro, A., 1996. Historia de la construcción medieval: aportaciones. Edicions UPC, Barcelona. Clemente, J.J., 2005. Evaluación de puentes arco de fábrica. Introducción al análisis con el MEF. Como, M., 2009. The collapse of the Beauvais Cathedral in 1284. The conjecture of the creep buckling piers. Presented at the 3th International Congress on Construction History, Cottbus. Corradi, M., Borri, A., Vignoli, A., 2003. Experimental study on the determination of strength of masonry walls. Construction and Building Materials 17, 325-337. doi:10.1016/S0950-0618(03)00007-2 Costanzo, A., Minasi, M., Casula, G., Musacchio, M., Buongiorno, M.F., n.d. Combined use of terrestrial laser scanning and IR thermography applied to a historical building. Sensors 15, 194-213. doi:10.3390/s150100194 Creazza, G., Satta, A.V., Matteazzi, R., Vitaliani, R.V., 2001. Analysis of masonry structures reinforced by FRP. Presented at the Historical constructions 2001: possibilities of numerical and experimental techniques, Guimarães, pp. 539-546. Croci, G., 2001a. Restoring the Basilica of St Francis of Assisi. CRM Cultural



Resource Management 24, 26?29.Croci, G., 2001b. Strengthening of monuments under the effect of static loads, soil settlements and seismic actions. Examples. Presented at the Historical constructions 2001: possibilities of numerical and experimental techniques, University of Minho, Guimarães, pp. 1167?1190.Croci, G., 2000a. Emergency stabilization of the Basilica of St. Francis of Assisi. CRM Cultural Resource Management 23, 30?32.Croci, G., 2000b. General methodology for the structural restoration of historic buildings: the cases of the Tower of Pisa and the Basilica of Assisi. Journal of Cultural Heritage 1, 7?18. doi:10.1016/S1296-2074(99)00119-3Cultrone, G., Sebastián, E., Ortega, M., 2007. Durability of masonry systems: A laboratory study. Construction and Building Materials 21, 40?51. doi:10.1016/j.conbuildmat.2005.07.008Curcio, L.C., 1968. Estudios y reflexiones sobre estructuras medievales y equilibrio de la catedral gotica de Reims. Mac Gaul, Buenos Aires.Dadkhah, F., Zecher, J., 2009. Ansys Workbench software tutorial with multimedia CD: release 12. Schroff Development Corporation, Mission, KS.Dalla, M., 2015. Qualificazione di murature storiche: procedure sperimentali in sito e calibrazioni in laboratorio.Dialer, C., 1991. Some remarks on the strength and deformation behaviour of shear stressed masonry panels under static monotonic loading. Presented at the 9th International Brick Masonry Conference, Berlín, pp. 276?283.Diamanti, N., Giannopoulos, A., Forde, M.C., 2008. Numerical modelling and experimental verification of GPR to investigate ring separation in brick masonry arch bridges. NDT & E International 41, 354?363. doi:10.1016/j.ndteint.2008.01.006Escrig, F. (Ed.), 2004a. Análisis de estructuras de obras de fábrica. Star. Structural Architecture 11, 3?89.Escrig, F. (Ed.), 2004b. Análisis dinámico de edificios históricos. Espadaña de la Iglesia de Santa María de la Blanca. Sevilla. Star. Structural Architecture 9, 3?63.Escrig, F. (Ed.), 2004c. Métodos de análisis para la rehabilitación de estructuras. Star. Structural Architecture 10, 3?101.Fedele, R., Maier, G., 2007. Flat-jack tests and inverse analysis for the identification of stress states and elastic properties in concrete dams. Meccanica 42, 387?402. doi:10.1007/s11012-007-9061-yFitchen, J., 1981. The construction of Gothic cathedrals; a study of medieval vault erection. University of Chicago Press, Chicago.Fraile M., J., García, P., Fraile A., J., 2013. Instrumentación aplicada a la ingeniería. Garceta, Madrid.Franco, V., 2011. Caracterización y modelado de estructuras del patrimonio histórico (masters). Univesitat Politècnica de Catalunya.G Baronio, L Binda, Tedeschi, C., Tiraboschi, C., 2003. Characterisation of the materials used in the construction of the Noto Cathedral. Construction and Building Materials 17, 557?571. doi:10.1016/j.conbuildmat.2003.08.007Gálvez, J.C, Reyes, E., Casati, M.J, 2004. Comportamiento mecánico de estructuras de fábrica de ladrillo. Hormigón y acero 234, 121?134.G. Vasconcelos, Lourenco, P.B, 2009. Experimental characterization of stone masonry in shear and compression. Construction and Building Materials 23, 3337?3345. doi:10.1016/j.conbuildmat.2009.06.045Gens, A., Alonso, E., 1989. Instrumentación de obras. Universitat Politècnica de Catalunya, Barcelona.Giunta, G., 2004. Architectural survey and non destructive investigations for conservative restoration of monuments. Presented at the 1st International workshop on Science, technology and cultural heritage, Venice.Giunta, G., Calloni, G., 2000. Ground Penetrating Radar applications on the Façade of St. Peter's Basilica in Vatican. Presented at the 15 th World Conference on Non-Destructive Testing, Rome.Gómez, J.L, Ruata, M.E, 2003. Comportamiento estructural de la iglesia de la Compañía de Jesús. Montevideo.Gregorczyk, P., Lourenco, P.B, 2000. A review on flat-jack testing. Engenharia Civil 9, 39?50.Grinzato, E., Marinetti, S., Bison, P.G, Concas, M., Fais, S., 2004. Comparison of ultrasonic velocity and IR thermography for the characterisation of stones. Infrared Physics & Technology 46, 63?68. doi:10.1016/j.infrared.2004.03.009Herbert, D.M, Gardner, D.R, Harbottle, M., Thomas, J., Hughes, T.G, 2011. The development of a new method for testing the lateral load capacity of small-scale masonry walls using a centrifuge and digital image correlation. Construction and Building Materials 25, 4465?4476. doi:10.1016/j.conbuildmat.2011.02.002Heyman, J., 2009. La Coupe des Pierres. Presented at the 3th International Congress on Construction History, Cottbus.Heyman, J., Huerta, S., 1995. Teoría, historia y restauración de estructuras de fábrica: colección de ensayos. Instituto Juan de Herrera, Escuela Técnica Superior de Arquitectura. CEHOPU. CEDEX, Madrid.Huerta, S., 2010. The safety of masonry buttresses. Proceedings of the ICE - Engineering History and Heritage 163, 3?24. doi:10.1680/ehah.2010.163.1.3Huerta, S., 2008. The Analysis of Masonry Architecture: A Historical Approach. Architectural Science Review 51, 297?328. doi:10.3763/asre.2008.5136Huerta, S., 2005. Mecánica de las bóvedas de fábrica. El enfoque del equilibrio. Informes de la Construcción 56, 73?89. doi:10.3989/ic.2005.v57.i496.496Huerta, S., 2004. Arcos, bóvedas y cúpulas. Geometría y equilibrio en el cálculo tradicional de estructuras de fábrica. Instituto Juan de Herrera, Madrid.Hughes, T.G, International Symposium on Computer Methods in Structural Masonry (Eds.), 2003. Computer methods in structural masonry V. Computers & Geotechnics Ltd, Swansea.Hughes, T.G, Pande, G.N, International Symposium on Computer Methods in Structural



Masonry (Eds.), 2004. Computer methods in structural masonry VI. Computers & Geotechnics, Sketty, Swansea [Wales]. Ignatakis, C., Stavrakakis, E., Penelis, G., 1993. Mechanical characteristics of ancient Roman masonry. Presented at the IABSE Colloquim. Structural preservation of the architectural heritage, Rome, pp. 433?440. doi:<http://dx.doi.org/10.5169/seals-53327> Irizarry, J., Podesta, S., Resemini, S., 2003. Curvas de capacidad para edificios monumentales: la Iglesia Santa María del Mar de Barcelona. Presented at the 2o Congreso Nacional de Ingeniería Sísmica, Málaga, pp. 541?555. Jurado, F., 2007. Interventions on ancient buildings structure. Presented at the International Workshop Preservation of Natural Stone and Rock Weathering, Madrid. Jurado, F., 1996. Análisis vectorial automático en la restauración de monumentos. Jurina, L., 2007. La caratterizzazione meccanica delle murature. Parte prima: prove penetrometriche. Parte seconda: martinetti piatti. Parte terza: prove dinamiche. Presented at the Seminario Internazionale C.I.A.S. Kadam, S., Singh, Y., Bing, L., 2015. Out-of-plane behaviour of unreinforced masonry strengthened using ferrocement overlay. Materials and Structures 48, 3187?3203. doi:[10.1617/s11527-014-0390-8](https://doi.org/10.1617/s11527-014-0390-8) Kamal, O.A., Hamdy, G.A., El-Salakawy, T.S., 2014. Nonlinear analysis of historic and contemporary vaulted masonry assemblages. HBRC Journal 10, 235?246. doi:[10.1016/j.hbrj.2013.11.004](https://doi.org/10.1016/j.hbrj.2013.11.004) Kaushik, H., Rai, D., Jain, S., 2007. Stress-strain characteristics of clay brick masonry under uniaxial compression. Journal of Materials in Civil Engineering 19, 728?739. doi:[10.1061/\(ASCE\)0899-1561\(2007\)19:9\(728\)](https://doi.org/10.1061/(ASCE)0899-1561(2007)19:9(728)) L Binda, C Tiraboschi, Baronio, G., 2003. On-site investigation on the remains of the Cathedral of Noto. Construction and Building Materials 17, 543?555. doi:[10.1016/S0950-0618\(03\)00057-6](https://doi.org/10.1016/S0950-0618(03)00057-6) Lasagabaster, J.I., Congreso Europeo sobre Restauración de Catedrales Góticas (Eds.), 2001. I Congreso Europeo de Restauración de Catedrales Góticas. Diputación Foral de Álava, Vitoria-Gasteiz. Lawrence, K., 2012a. Ansys tutorial: release 14: structural & thermal analysis using the Ansys Mechanical APDL release 14 environment. SDC Publications, Mission, KS. Lawrence, K., 2012b. Ansys Workbench tutorial: structural & thermal analysis using the Ansys Workbench release 14 environment. Schroff Development Corp., Mission, Kan. Lee, H-H., 2014. Finite Element Simulations with ANSYS Workbench 15. SDC publications, Mission. León, J., Corres, H., Espejo, S., 2007. Obras de fábrica. Sostenibilidad e ingeniería. León, J., Martínez, J., Martín-Caro, J.A., 2000. La torre de la Silla de la Reina en la Catedral de León. Leonhardt, F., 1997. The committee to save the tower of Pisa: a personal report. Structural Engineering International 7, 201?212. doi:[10.2749/101686697780494734](https://doi.org/10.2749/101686697780494734) Lombillo, I., Agudo, E., Villegas, L., 2007. Evaluación no destructiva del patrimonio construido. Inspección visual. Técnicas acústicas electromagnéticas y tomográficas. Presentado al 11o Congreso Español de Ensayos No Destructivos, Gijón. Lombillo, I., Villegas, L., 2008. Campaña experimental cuasi-no destructiva desarrollada en elementos estructurales de fábrica: Ensayos in situ y en laboratorio. Presented at the 3as. Jornadas Internacionales sobre Tecnología de la Rehabilitación y Gestión del Patrimonio Construido (REHABEND), Valencia. Lombillo, I., Villegas, L., 2006. Metodologías no destructivas aplicadas a la rehabilitación estructural del patrimonio. Presented at the Metodologías no destructivas aplicadas a la rehabilitación del patrimonio construido (REHABEND). Lombillo, I., Villegas, L., Elices, J., 2010. Minor destructive techniques applied to the mechanical characterization of historical rubble stone masonry structures. Structural Survey 28, 53?70. doi:[10.1108/02630801011040860](https://doi.org/10.1108/02630801011040860) Lombillo, I., Villegas, L., Elices, J., 2009. Non minor destructive methodologies applied to the study and diagnosis of masonry structures of the building heritage. A state of the art. Presented at the I Congreso Internacional de Investigación en Edificación (COINVEDI), Madrid. López, J., Oller, S., Oñate, E., 1998. Cálculo del comportamiento de la mampostería mediante elementos finitos, Monografía CIMNE. Centro Internacional de Métodos Numéricos en Ingeniería, Barcelona. Lourenco, P.B., 2002. Computations on historic masonry structures. Prog. Struct. Engng Mater. 4, 301?319. doi:[10.1002/pse.120](https://doi.org/10.1002/pse.120) Lourenco, P.B (Ed.), 2001. Historical constructions 2001: possibilities of numerical and experimental techniques. University of Minho, Guimarães. Lourenco, P.B., 2000. A macro-model for the out-of-plane behaviour of masonry. Presented at the 12th International Brick Masonry Conference, Madrid. Lourenco, P.B., 1998. Experimental and numerical issues in the modelling of the mechanical behaviour of masonry. Presented at the Structural Analysis of Historical Constructions II, Barcelona. Lourenco, P.B., 1996. Computational strategies for masonry structures. TU Delft. Lourenco, P.B., 1995. An orthotropic continuum model for the analysis of masonry structures. Lourenco, P.B., 1994. Analysis of masonry structures with interface elements. Lourenco, P.B., Barros, J.O., Almeida, J.C., 2002. Characterization of masonry under uniaxial tension. Lourenco, P.B., International Seminar on Structural Analysis of Historical Constructions (Eds.), 2007. Structural analysis of historical constructions V: possibilities of numerical and experimental techniques. Macmillan, New Delhi. Lourenco, P.B., Milani, G., Tralli, A., Zucchini, A., 2007. Analysis of masonry structures: review of and recent



trends in homogenization techniques This article is one of a selection of papers published in this Special Issue on Masonry. Canadian Journal of Civil Engineering 34, 1443?1457. doi:10.1139/L07-097 Lourenco, P.B., Oliveira, D.V., 2007. Improving the seismic resistance of masonry buildings: concepts for cultural heritage and recent developments in structural analysis. Presented at the XII Convegno Nazionale ANIDIS L'Ingegneria Sismica in Italia, Pisa. Lourenco, P.B., Rots, J.G., Blaauwendraad, J., 1998. Continuum model for masonry. parameter estimation and validation. Journal of Structural Engineering 124, 642?652. doi:http://dx.doi.org/10.1061/(ASCE)0733-9445(1998)124:6(642) Lourenco, P.B., Vasconcelos, G., Gouveia, J.P., Haach, V., 2006. Current experimental investigations on modern masonry at University of Minho. Presented at the Comission Meeting and Workshop: proceedings, Lisboa. Ludovico-Marques, M., Chastre, C., Vasconcelos, G., 2012. Modelling the compressive mechanical behaviour of granite and sandstone historical building stones. Construction and Building Materials 28, 372?381. doi:10.1016/j.conbuildmat.2011.08.083 Luigia Binda, Lenzi, G., Saisi, A., 1998. NDE of masonry structures: use of radar tests for the characterisation of stone masonries. NDT & E International 31, 411?419. doi:10.1016/S0963-8695(98)00039-5 Luigia Binda, Lualdi, M., Saisi, A., 2007. Non-Destructive Testing Techniques Applied for Diagnostic Investigation: Syracuse Cathedral in Sicily, Italy. International Journal of Architectural Heritage 1, 380?402. doi:10.1080/15583050701386029 Macchi, G., 2001. Diagnosis of the facade of St Peters Basilica in Rome. Presented at the 3rd International Seminar on Structural Analysis of Historical Constructions, Guimarães, pp. 309?318. Madenci, E., Guven, I., 2015. The finite element method and applications in engineering using Ansys. Springer US, Boston, MA. Mark, R., 1995. Architectural technology up to the scientific revolution: the art and structure of large-scale buildings. MIT Press, Cambridge, Mass. Mark, R., 1982. Experiments in gothic structure. MIT Press. Mark, R., Gómez, J.M., López, D., 2002. Tecnología arquitectónica hasta la revolución científica: arte y estructura de las grandes construcciones. Akal Ediciones, Tres Cantos, Madrid. Martínez, J.L., 2003. Determinación teórica y experimental de diagramas de interacción de esfuerzos en estructuras de fábrica y aplicación al análisis de construcciones históricas. E.T.S.I. Caminos, Canales y Puertos (UPM). Martínez, J.L., Martín-Caro, J.A., León, J., 2003. Evaluación estructural de puentes arco de fábrica, Monografías sobre el análisis estructural de construcciones históricas de fábrica. Universidad Politécnica de Madrid, Madrid. Masciotta, M.G., Roque, J.C.A., Ramos, L.F., Lourenco, P.B., 2016. A multidisciplinary approach to assess the health state of heritage structures: The case study of the Church of Monastery of Jerónimos in Lisbon. Construction and Building Materials 116, 169?187. doi:10.1016/j.conbuildmat.2016.04.146 Mas-Guindal, A.J., 2011. Mecánica de las estructuras antiguas. Munilla-Leira, Madrid. Mas-Guindal, A.J., 2005. La concepción estructural de la fábrica en la arquitectura. Informes de la Construcción 56, 3?12. doi:10.3989/ic.2005.v57.i496.458 Mas-Guindal, A.J., 1998. La reparación de la estructura. Fundación Cultural COAM, Madrid. Mete, O., 2012. Structural modelling analysis evaluation and strengthening of Perge Southern Gate hellenistic towers. Middle East Technical University, Ankara. Moaveni, S., 2008. Finite element analysis: Theory and application with Ansys, 3rd. ed. ed. Pearson, Upper Saddle River (New Jersey). Modena, C., Lourenco, P.B., Roca, P., International seminar on structural analysis of historical constructions (Eds.), 2005. Structural analysis of historical constructions IV: possibilities of numerical and experimental techniques. A. A. Balkema publishers, Leiden. Mojsilovic, N., 2011. Strength of masonry subjected to in-plane loading: A contribution. International Journal of Solids and Structures 48, 865?873. doi:10.1016/j.ijsolstr.2010.11.019 Molins, C., 1996. Un model per l'anàlisi del comportament resistent de construccions de maçoneria (info:eu-repo/semantics/doctoralThesis). Univesitat Politècnica de Catalunya. Montazerolghaem, M., Wolfram, J., 2014. A comparative numerical evaluation of masonry initial shear test methods and modifications proposed for EN 1052-3. Presented at the 9th International Masonry Conference, Guimarães. Nakasone, Y., Stolarski, T.A., Yoshimoto, S., 2011. Engineering analysis with Ansys software. Butterworth-Heinemann. Nardini, L., 2001. Indagine numerica e sperimentale sul comportamento statico e dinamico della torre di Matilde in San Miniato. Università degli Studi di Pisa, Pisa. Nichols, J.M., Totoev, Y.Z., 2012. Experimental investigation of the damage mechanics of masonry under dynamic in-plane loads. Norbert, B., Snethlage, R., Dahlem Workshop on Saving our Architectural Heritage (Eds.), 1997. Saving our architectural heritage: the conservation of historic stone structures. J. Wiley, Chichester; New York. Oliveira, D.V., 2000a. Mechanical characterization of stone and brick masonry. Oliveira, D.V., 2000b. Mechanical characterization of stone and brick masonry. Oliveira, D.V., Lourenco, P.B., Roca, P., 2000. Comportamento experimental de muros de pedra sujeitos a esforços de compressão e corte. Presented at the Encontro Nacional sobre Conservação e Reabilitação de Estruturas. Oller, S., 2014. Numerical simulation of mechanical behavior of composite materials, Lecture Notes on



Numerical Methods in Engineering and Sciences. Springer International Publishing. Page, A.W, 1982. An experimental investigation of the biaxial strength of brick masonry. Presented at the 6th International Brick Masonry Conference, Rome, pp. 3?15. Page, A.W, 1981. The biaxial compressive strength of brick masonry. Proceedings of the Institution of Civil Engineers 71, 893?906. doi:10.1680/icep.1981.1825 Page, A.W, 1979. A model for the in-plane behaviour of masonry and a sensitivity analysis of its critical parameters. Presented at the 5th International Brick Masonry Conference. Pande, G.N, Middleton, J., Kralj, B., International Symposium on Computer Methods in Structural Masonry (Eds.), 1998. Computer methods in structural masonry IV. E & FN Spon, London; New York. Parent, T., Domede, N., Sellier, A., Dujarrier, C., 2014. Structural analysis of masonry historical construction. Ribbed-vault case study. Paricio, I, 2000. La construcción de la arquitectura. Instituto de Tecnología de la Construcción de Cataluña, Barcelona. Pau, A., Vestroni, F., 2013. Vibration assessment and structural monitoring of the Basilica of Maxentius in Rome. Mechanical Systems and Signal Processing 41, 454?466. doi:10.1016/j.ymssp.2013.05.009 Plevris, V., Asteris, P.G, 2014. Modeling of masonry failure surface under biaxial compressive stress using Neural Networks. Construction and Building Materials 55, 447?461. doi:10.1016/j.conbuildmat.2014.01.041 Porto, F., Modena, C., Valluzzi, M.R, 2004. Experimental tests on irregular masonry. Rabasa, E., 2000. Forma y construcción en piedra: de la cantería medieval a la estereotomía del siglo XIX. Akal Ediciones, Madrid, España. Ramírez, A, 1993. El acueducto de Segovia. Revista de Obras Públicas 140, 7?18. Reyes, E., Casati, M.J, Gálvez, J.C, 2003. Estudio de la rotura de la fábrica de ladrillo bajo solicitaciones de tracción y cortante. Hormigón y acero 230, 43?55. Riddington, J.R, Ghazali, M.Z, 1988. Shear strength of masonry walls. Presented at the 8th International Brick Masonry Conference, London. Rieg, F, Hackenschmidt, R., Alber-Laukant, B., 2014. Finite element analysis for engineers: basics and practical applications with Z88Aurora. Textstream. Roa, M.A, Garzón, D.A, 2002. Introducción al modelamiento por elementos finitos con Ansys. Roca, P., Cervera, M., Gariup, G., Pela, L., 2010. Structural analysis of masonry historical constructions. Classical and advanced approaches. Archives of Computational Methods in Engineering 17, 299?325. doi:10.1007/s11831-010-9046-1 Roca, P., International seminar on structural analysis of historical constructions (Eds.), 1998. Structural analysis of historical constructions II: possibilities of numerical and experimental techniques. International Center for Numerical Methods in Engineering, Barcelona. Roca, P., International seminar on structural analysis of historical constructions (Eds.), 1997. Structural analysis of historical constructions I: possibilities of numerical and experimental techniques. CIMNE, Barcelona. Roca, P., Lodos, J.C, 2001. Análisis estructural de catedrales góticas. O.P. Ingeniería y Territorio 56, 38?47. Roca, P., Molins, C., Carol, I., 2000. Análisis de edificios de muros de carga de mampostería ante acciones horizontales. Hormigón y acero 215, 115?126. Rolando, A., 2006. Resistencia característica a compresión de una fábrica de ladrillo en función de la resistencia de sus componentes. Materiales de Construcción 56, 91?98. doi:10.3989/mc.2006.v56.i283.11 Roque, J.C.A, Lourenco, P.B, 2003. Caracterização mecânica de paredes antigas de alvenaria?: um caso de estudo no centro histórico de Bragança. Engenharia Civil 17, 31?42. Rosas, J.G, Villegas, L.M, Lorenzo, D., 2001. Aplicación de modelos numéricos al estudio del comportamiento de muros de cortante en estructuras de fábrica. Hormigón y acero 221, 69?82. Rossi, P.P, 1995. Possibilities of numerical and experimental techniques. Presented at the International seminar on structural analysis of historical constructions, Barcelona. Sánchez-Beitia, S., Brebbia, C.A, International Conference on Structural Repair and Maintenance of Historical Building (Eds.), 1997. Structural studies, repairs and maintenance of historical buildings V. Computational Mechanics Publ., Southampton [u.a. Theodossopoulos, D., 2005. Structural scheme of the Cathedral of Burgos. Presented at the International seminar on structural analysis of historical constructions, Leiden, pp. 643?651. Thurlimann, B., Guggisberg, R., 1988. Failure criterion for laterally loaded masonry walls. Experimental investigations. Presented at the 8th International Brick Masonry Conference, London. Tringali, S., De Benedictis, R., La Rosa, R., Russo, C., Bramante, A., Gavarini, C., Valente, G., Ceradini, V., Tocci, C., Tobriner, S., Maugeri, M., L Binda, Baronio, G., 2003. The reconstruction of the Cathedral of Noto. Construction and Building Materials 17, 573?578. doi:10.1016/S0950-0618(03)00052-7 Umair, S., Numada, M., Amin, M., Kimiro, M., 2015. Fiber Reinforced Polymer and Polypropylene Composite Retrofitting Technique for Masonry Structures. Polymers 7, 963?984. doi:10.3390/polym7050963 Valcárcel, J.B, Martín, E., Domínguez, E., Escrig, F., 2001. Structural modelling of medieval walls. Presented at the Historical constructions 2001: possibilities of numerical and experimental techniques, Guimarães, pp. 501?510. Valle, J.M, Rodríguez, A., Pérez, P., 2008. Evaluation of the contentional surveying equipment applied to deformation analysis of heritage buildings. Presented at the 13th FIG International Symposium on Deformation Measurements and Analysis, Lisbon. Van der Mersch, M.A, 2015. Modelling the seismic response of



an unreinforced masonry structure (Master thesis). TU Delft, Delft University of Technology. Vasconcelos, G., Lourenco, P.B., 2006. Assessment of the in-plane shear strength of stone masonry walls by simplified models. Presented at the International Conference on Structural Analysis of Historical Constructions, MacMillan, New Delhi. Vasconcelos, G., Lourenco, P.B., Mouzakis, H., Karapitta, L., 2006. Experimental investigations on dry stone masonry walls. Presented at the International Conference on Restoration of Heritage Masonry Structures, Cairo. Vermeltfoort, A., 2004. Shear bond and 2d compressive properties of thin bed mortar masonry. Presented at the 13th International Brick and Block Masonry Conference, Amsterdam. Villegas, L., Lombillo, I., Agudo, E., 2007. Evaluación no destructiva del patrimonio construido. Técnicas basadas en aspectos tensionales. Presented at the 11o Congreso Español de Ensayos No Destructivos, Gijón. Viollet-le-Duc, E.E., 2000. La construcción medieval. Instituto Juan de Herrera. Woodham, D.B., 2001. Imaging structural elements of a cathedral using ground penetrating radar. Presented at the Structural Studies, Repairs and Maintenance of Historical Buildings VII, WIT Press, Bologna.



Recommendations

Subjects that it is recommended to have taken before

Subjects that are recommended to be taken simultaneously

Subjects that continue the syllabus

Other comments

Certain skills are required in the use of computer-aided design tools, as well as elementary knowledge about the theoretical bases of the finite element method.

(*)The teaching guide is the document in which the URV publishes the information about all its courses. It is a public document and cannot be modified. Only in exceptional cases can it be revised by the competent agent or duly revised so that it is in line with current legislation.