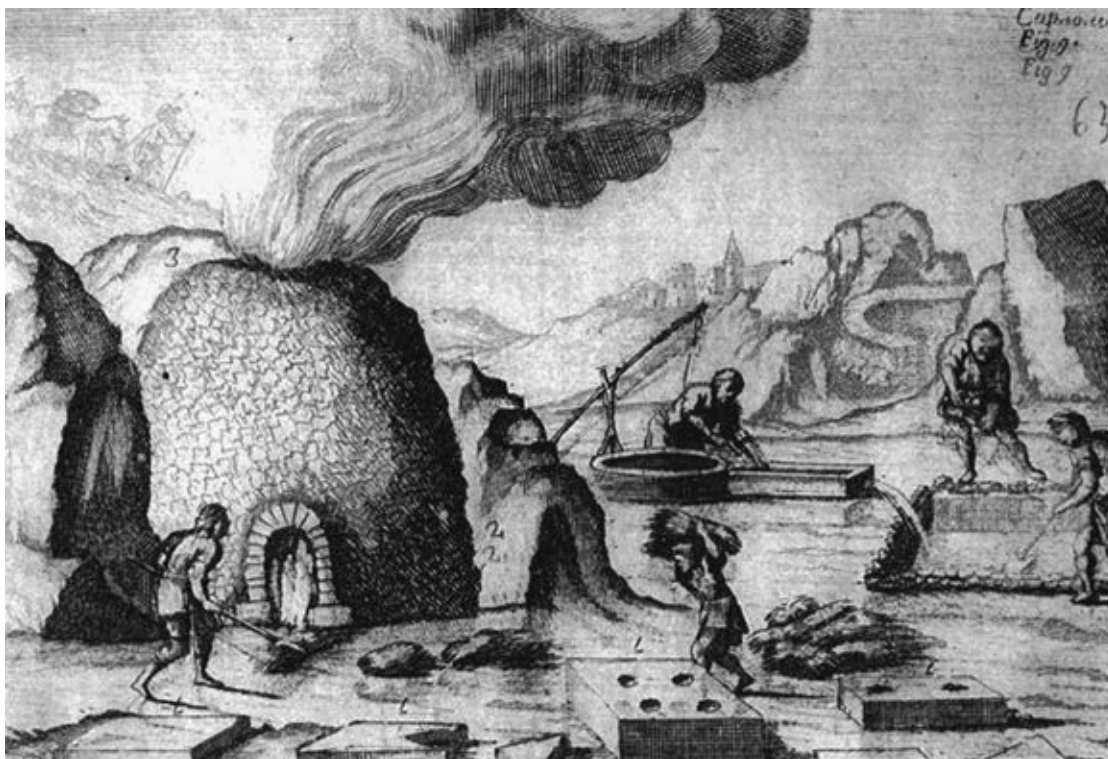


STEFANO CAMPOREALE
JANET DELAINE
ANTONIO PIZZO
(eds.)

ANEJOS
DE
AESPALXXVII



ARQUEOLOGÍA DE LA CONSTRUCCIÓN V

5th International Workshop on the Archaeology of Roman Construction

Man-made materials, engineering and infrastructure

ANEJOS DE ARCHIVO ESPAÑOL DE ARQUEOLOGÍA

LXXVII

ARQUEOLOGÍA DE LA CONSTRUCCIÓN V

Anejos de AESPA

Director: Ángel Morillo Cerdán, Universidad Complutense, Madrid, España.

Secretario: Carlos Jesús Morán Sánchez, Instituto de Arqueología, CSIC-Junta de Extremadura, Mérida, España.

Comité Editorial: Pedro Mateos Cruz, Instituto de Arqueología, CSIC-Junta de Extremadura, Mérida, España; Adolfo Domínguez Monedero, Universidad Autónoma, Madrid, España; Inés Sastre Prats, Instituto de Historia, CCHS, CSIC, Madrid, España; Miguel Cisneros Cunchillos, Universidad de Cantabria; José Miguel Noguera Celdrán, Universidad de Murcia, España; Victorino Mayoral Herrera, Instituto de Arqueología, CSIC-Junta de Extremadura, Mérida, España; Susana González Reyero, Instituto de Historia, CCHS, CSIC, Madrid, España; M.^a Ángeles Utrero Agudo, Instituto de Historia, CCHS, CSIC, Madrid, España.

Consejo Asesor: Francisco Pina Polo, Universidad de Zaragoza, España; Luis Caballero Zoreda, Instituto de Historia, CCHS, CSIC, España; María Paz García-Bellido, Instituto de Historia, CCHS, CSIC, Madrid, España; Juan Manuel Abascal Palazón, Universidad de Alicante, España; Filippo Coarelli, Università degli Studi di Perugia, Italia; Trinidad Tortosa Rocamora, Instituto de Arqueología, CSIC-Junta de Extremadura, Mérida, España; María Ruiz del Árbol Moro, Instituto de Historia, CCHS, CSIC, Madrid, España; Pilar León-Castro Alonso, Universidad de Sevilla, España; Almudena Orejas Saco del Valle, Instituto de Historia, CCHS, CSIC, Madrid, España; Carmen García Merino, Universidad de Valladolid, España; Javier Arce, Université Lille, Francia; Bárbara Böck, Instituto de Lenguas y Culturas del Mediterráneo y Oriente Próximo, CCHS, CSIC, Madrid, España; Domingo Plácido, Universidad Complutense de Madrid, España; Pietro Brogiolo, Università di Padova, Italia; Teresa Chapa Brunet, Universidad Complutense de Madrid, España; Monique Clavel-Lévêque, Université Franche-Comté, Besançon, Francia.

JANET DELAINE
STEFANO CAMPOREALE
ANTONIO PIZZO
(eds.)

ARQUEOLOGÍA DE LA CONSTRUCCIÓN
V

MAN-MADE MATERIALS,
ENGINEERING AND INFRASTRUCTURE

Proceedings of the 5th International Workshop on the Archaeology of Roman Construction
Oxford, April 11-12, 2015

CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS
MADRID, 2016

Reservados todos los derechos por la legislación en materia de Propiedad Intelectual. Ni la totalidad ni parte de este libro, incluido el diseño de la cubierta, puede reproducirse, almacenarse o transmitirse en manera alguna por medio ya sea electrónico, químico, óptico, informático, de grabación o de fotocopia, sin permiso previo por escrito de la editorial.

Las noticias, los asertos y las opiniones contenidos en esta obra son de la exclusiva responsabilidad del autor o autores. La editorial, por su parte, solo se hace responsable del interés científico de sus publicaciones.

Este volumen se ha beneficiado de los fondos del proyecto de investigación del VI Plan de Investigación «Análisis de soluciones técnico-constructivas, modelos arquitectónicos y urbanísticos de la arquitectura romana de Lusitania: orígenes y transformación de una cultura arquitectónica» (ref. HAR2012-36963-C05-05). Investigador principal: Dr. Antonio Pizzo.

Imagen de cubierta: Giovanni Biagio Amico, *L'architetto pratico*, vol. I, Palermo 1726

Imagen de contracubierta: detalle de la imagen anterior

Catálogo general de publicaciones oficiales:
<http://publicacionesoficiales.boe.es>

EDITORIAL CSIC: <http://editorial.csic.es> (correo: publ@csic.es)



© CSIC

© Janet DeLaine, Stefano Camporeale, Antonio Pizzo (eds.) y de cada texto, su autor

© De las ilustraciones, los autores y las instituciones mencionados a pie de figura

NIPO: 723-16-272-8

e-NIPO: 723-16-273-3

ISBN: 978-84-00-10142-8

e-ISBN: 978-84-00-10143-5

Depósito Legal: M-39482-2016

Maquetación, impresión y encuadernación: Gráficas Blanco, S. L.

Impreso en España. *Printed in Spain*

En esta edición se ha utilizado papel ecológico sometido a un proceso de blanqueado ECF, cuya fibra procede de bosques gestionados de forma sostenible.

SUMARIO

<i>Introduction</i>	9
J. DELAINE, S. CAMPOREALE, A. PIZZO	
I. CONCRETE TECHNOLOGY AND USE	
<i>Technological confidence in Late republican and imperial era Roman architectural and maritime concrete construction</i>	15
M. D. JACKSON	
<i>L'uso delle polveri pozzolaniche nei grandi cantieri della Gallia Cisalpina durante l'età romana repubblicana: i casi di Aquileia e Ravenna</i>	29
J. BONETTO, G. ARTIOLI, M. SECCO, A. ADDIS	
<i>Lime mortar production in Ostia: material analysis of mortar from the Hadrianic period</i>	45
J. WEHBY MURGATROYD	
II. STRUCTURAL AND CONSTRUCTIONAL USES OF METAL	
<i>The bronze truss of the portico of the Pantheon in Rome</i>	59
D. HEINZELMANN, M. HEINZELMANN	
<i>"Armored" columns in the Roman imperial period</i>	75
C. M. AMICI	
III. PRODUCTION, SUPPLY AND USE OF BRICK AND TILE	
<i>The social life of tile in the Roman world</i>	87
P. MILLS	
<i>Ceramic building material: production, supply and use in Roman London</i>	99
I. M. BETTS	
<i>Tegulae mammatae or lateres? On the presence and use of tegulae mammatae in the delta of the Rhine</i>	111
A. G. GAZENBEEK	
<i>The end of the tegulae mammatae? A review on their name, function(ality) and presence in the Roman North</i>	121
T. CLERBAUT	
IV. PRODUCTION, SUPPLY AND USE OF MUD-BRICK AND PISÉ DE TERRE	
<i>Mud brick and pisé de terre between Punic and Roman</i>	131
B. RUSSELL, E. FENTRESS	

<i>L'industrie de la brique crue dans la colonia Lugdunum. Typologie, approvisionnement et organisation de la production</i>	145
B. CLÉMENT	
V. LIFTING MACHINES IN THEORY AND PRACTICE	
<i>Taking a bearing on Hero's anti-crane and its un-windlass: the relationship between Hero of Alexandria's mobile automaton and Greco-Roman construction machinery, artillery and water-lifting machines.....</i>	167
D. KEENAN-JONES, I. RUFFELL, E. MCGOOKIN	
<i>Lifting blocks, 1st-5th century AD: the inclined plane.....</i>	185
G. MARTINES, M. BRUNO, C. CONTI	
<i>The restoration of the columns of the templum Castoris during Verres' praetorship: the machina and organisation of the building site</i>	201
P. DUCRET	
VI. PRACTICAL SOLUTIONS TO ENGINEERING PROBLEMS	
<i>Costruire in terreni paludosi: sistemi di fondazione e bonifica in uso in età romana in Italia settentrionale fra tradizione e innovazione</i>	209
C. PREVIATO	
<i>Facing structural problems in ancient times. A structural assessment during the construction of the Mausoleum of Hadrian.....</i>	231
P. VITTI	
VII. INFRASTRUCTURE AND ORGANISATION OF CONSTRUCTION	
<i>Les techniques et les étapes de la construction des salles de soutènement des thermes de Longeas (Chassenon, France)</i>	251
A. COUTELAS, D. HOURCADE	
<i>Tracce di cantiere dall'area del Capitolium di Brescia: evidenze archeologiche e materiali dai recenti scavi</i>	275
A. DELL'ACQUA	
<i>The 'Lower Agora' of Pergamon. The organisation of a major building site in Roman Asia Minor.....</i>	299
B. EMME, A. ÖZTÜRK (†)	
VIII. THE ORGANISATION OF CONSTRUCTION IN REPUBLICAN AND PRE-REPUBLICAN ITALY	
<i>Quantifying monumentality in a time of crisis. Building materials, labour force and building costs in Late Republican central Italy</i>	317
D. MASCHEK	
<i>Networks and workshops. Construction of temples at the dawn of the Roman Republic.....</i>	331
P. S. LULOF	
<i>Conclusions.....</i>	343
L. C. LANCASTER	

INTRODUCTION

JANET DELAINE, STEFANO CAMPOREALE, ANTONIO PIZZO

The archaeology of construction is a relatively new discipline within the broader field of Roman architecture. It was given a major impetus by the efforts of an active international group of researchers to create a series of workshops on the subject. Thanks to Antonio Pizzo of the Archaeological Institute of Mérida, Stefano Camporeale of the University of Siena, and Hélène Dessales of the Ecole normale supérieure in Paris, the initial series of workshops began in 2007 at Mérida, quickly followed in 2008 at Siena, and in 2010 at Paris. Given their enormous success, and with the invaluable contribution of Jacopo Bonetto of the University of Padua, it was decided to extend the series with a further workshop in 2012.¹

The great success of these previous four workshops demonstrated the very strong interest which exists among scholars of Roman history and archaeology in the constructional aspects of Roman architecture. This discipline can be briefly defined as the study of the processes involved in Roman construction projects, covering the production and supply of materials, the techniques used in construction, and the problems of logistics, manpower, and the economics. The archaeology of Roman construction is seen as complementary to the more traditional areas of the study of Roman architecture, such as building typologies and use, design and decoration, or the func-

tion of the finished buildings in society, but also uniquely has the potential to contribute much to ongoing debates about the size and shape of Roman urban economies.

The previous workshops looked at the question of ‘cantieri’ – building sites and processes – first in Italy and west (Mérida) and then Italy and the eastern Roman provinces (Siena), while the Paris meeting focused on the economic aspects, and the Padua workshop concentrated on the quarrying and supply of building stone. The broad focus of this present workshop is on the development of specific technologies for solving constructional or structural problems, including the production and supply of man-made materials, the contribution of engineering and machines to the functioning of building sites, and the nature and division of labour these require. It has also tried – with some success – to bring into the discussion the north-western provinces, and less-frequently discussed materials as diverse as metals, mud-brick and *pisé de terre*.

Alongside the naturally occurring materials of stone and timber, Roman builders used a wide variety of materials that had to go through one or more sequences of processing, usually at a separate production site or more rarely, for example in the case of mortar, on site. The supply of bulk materials such as brick and mortar are key in the logistics of site construction, while speciality products such as metal elements usually represent special and sometimes unique solutions to specific structural and constructional problems. Man-made materials also often required high levels of skilled manpower and specialised equipment or plant in their processing, thus contributing substantially to the cost of construction.

¹ For the archaeology of construction see DeLaine 1997; *Cantieri antichi* 2002; and the chapter by Hélène Dessales in Bukowiecki *et al.* 2008: 19-24. For the proceedings of the workshops see Camporeale *et al.* 2008; Camporeale *et al.* 2010; Camporeale *et al.* 2012; Bonetto *et al.* 2014; syntheses of the results of the first workshops are in Pizzo 2009 and Camporeale 2010.

The volume is divided into eight sections, corresponding to the four pairs of sessions which constituted the workshop. The first session, on concrete technology and use, began with the most common and most typically Roman of all man-made materials – pozzolanic mortar. Here advances in scientific analyses are proving fundamental in advancing our understanding not only of what materials were used and how, but also where, geographically, and in what contexts they were used, and the chronology of use. In contrast, metal (session II) is much less well-known as a building material in the Roman world; the papers on the structural and constructional uses of metal give new insights into both bronze and iron technology and its applications.

The third and fourth sessions were devoted to the production, supply and use of building materials made of fired clay and of earth. Building materials of fired clay (which the British call CBM or ‘ceramic building materials’) and including brick, tile, wall tubes, and vaulting tubes, are, like mortar, one of the hallmarks of Roman construction, and one of the most ubiquitous and certainly the most widespread materials in the archaeological record. Yet they have tended not to be treated as a main focus of study, although the recent conference in Rome has gone a considerable way to redressing the situation.² Even more neglected in standard accounts of Roman construction, however, are materials made of unfired earth, mud brick and *pisé de terre*, often very difficult to detect in the archaeological record; furthermore they are certainly rarely brought into the same discourse as fired brick and pozzolanic mortar. Yet the papers presented here argue that they were at least as common, and not only in earlier periods or rural vernacular constructions.

In the fifth session attention was focused on engineering and machines. The Romans have long been admired for their engineering skills, but this is an area which has so far attracted relatively little interest within the archaeology of construction. Large-scale construction is not possible without the use of complex lifting machines, or devices such as the truss, used in supporting large formwork, yet all of these require specialised equipment and skills, and have an impact on the scheduling of work and the division of labour. Machines, especially the lifting machines essential for large-scale construction, are particularly

under-researched in relation to construction processes, something that the papers in the section on lifting machines in theory and practice go part way to addressing. The papers in the sixth session looked specifically at practical solutions to engineering problems, and in particular the problems of foundations – another often invisible element in construction – in relation to actual site conditions, helping to throw light on construction processes, the choices made by builders and architects, and their responses to building on unstable ground.

The final pair of sessions returned to themes more familiar from earlier workshops, especially the infrastructure and organisation of construction. These provided some rare surviving evidence of building work in progress, and discuss strategies used for construction where resources were limited. The final pair of papers continue the theme but with a chronological emphasis, examining seasonal demands for resources and manpower in the Republican period, and identifying networks of production in pre-Republican Italy. These papers all bring us as close as possible to the individual human actors – the builders – who are, ultimately, the real focus of our common interest, the archaeology of Roman construction.

The workshop in Oxford attracted a great deal of interest, with almost 60 proposals for papers, and over 80 delegates and speakers, from 10 different countries. One of the guiding principles for the workshop was to maintain the wide range of approaches and the multidisciplinary nature which characterised the earlier four. As befits a workshop, the emphasis was on discussion and the exchange of ideas, elements which made the previous ones so fruitful and enjoyable. Given the very large number of high quality proposals for papers, it was therefore decided for the first time to include posters as an integral part of the workshop, divided into their appropriate sessions and included in the discussion at the end of each session. Several of these are being published in the journal *Arqueología de la arquitectura*, forming an important complement to the papers presented in this volume.

Finally the editors would like to thank the Classics Faculty Board, the Craven Committee, the Meyerstein Research Fund of the School of Archaeology, and the Lorne Thyssen Research Fund for Ancient World Topics at Wolfson College, all of the University of Oxford, and the RSK Group for their generous support of this workshop. Particular thanks go to the Consejo Supe-

² Bukowiecki *et al.* 2015.

rior de Investigaciones Científicas, who, since the first workshop, has continued to finance the publication of the series *Arqueología de la construcción* in the *Anejos de Archivo Espanol de Arqueología*. Finally, we would like to thank the Workshop secretary, Alejandra Albuérne, for her outstanding contribution to the whole organisation of the workshop, Kate del Nevo of the Faculty of Classics for her logistical support, and the graduate volunteers from the School of Archaeology.

REFERENCES

- BONETTO, J., CAMPOREALE, S. and PIZZO, A. (a cura di) 2014: *Arqueología de la Construcción IV. Las cante-
ras en el mundo antiguo: sistemas de explotación y
procesos productivos* (Padova, 22-24 de noviembre
de 2007), *Anejos de Archivo Español de Arqueología*
69. CSIC, Mérida.
- BUKOWIECKI, E., DESSALES, H. and DUBOULOZ, J. 2008:
*Ostie, l'eau dans la ville. Châteaux d'eau et réseau
d'adduction*, Collection de l'Ecole française de
Rome 402. Ecole française de Rome, Rome.
- BUKOWIECKI, E., VOLPE, R., WULF-RHEIDT, U. 2015:
"Il laterizio nei cantieri imperiali. Roma ed il Medi-
terraneo", *Archeologia dell'Architettura*, 20, in press.
- CAMPOREALE, S. 2010: "Archeologia dei cantieri di
età romana", *Archeologia dell'architettura*, 15, pp.
171-179.
- CAMPOREALE, S., DESSALES, H. and PIZZO, A. (a cura
di) 2008: *Arqueología de la Construcción I. Los pro-
cesos constructivos en Italia y en las provincias roma-
nas: Italia y provincias occidentales* (Mérida, 26-27
de octubre de 2007), *Anejos de Archivo Español de
Arqueología* 50. CSIC, Mérida.
- CAMPOREALE, S., DESSALES, H. and PIZZO, A. (a cura
di) 2010: *Arqueología de la Construcción II. Los pro-
cesos constructivos en Italia y en las provincias roma-
nas: Italia y provincias orientales* (Siena, 13-15 de
noviembre de 2008), *Anejos de Archivo Español de
Arqueología* 57. CSIC, Madrid-Mérida.
- CAMPOREALE, S., DESSALES, H. and PIZZO, A. (a cura
di) 2012: *Arqueología de la Construcción III. Los
procesos constructivos en el mundo romano: la econo-
mía de las obras* (París, 10-11 de diciembre de 2009),
Anejos de Archivo Español de Arqueología 69. CSIC,
Madrid-Mérida.
- CANTIERI ANTICHI 2002: "Cantieri antichi. Giornata di
studio tenuta il 25 ottobre 2001", *Römische Mit-
teilungen*, 109, pp. 340-429.
- DELAINE, J. 1997: *The Baths of Caracalla. A Study in
the Design, Construction, and Economics of Large-
scale Building Projects in Imperial Rome*, *Journal of
Roman Archaeology* Suppl. 25. Journal of Roman
Archaeology, Portsmouth, R. I.
- PIZZO, A. 2009: "La Arqueología de la Construcción.
Un laboratorio para el análisis de la arquitectura de
época romana", *Arqueología de la arquitectura*, 6,
pp. 31-45.

