



Engineering, Aqueducts, and the Rupture of Knowledge Transmission in the Visigothic Period

JAVIER MARTÍNEZ JIMÉNEZ
CHURCHILL COLLEGE/FACULTY OF CLASSICS, UNIVERSITY OF CAMBRIDGE

ABSTRACT

The agitated existing debate between traditional historiography and revisionist positions regarding the nature of the so-called “Visigothic” churches derives, fundamentally, from the proposal that a series of techniques and skills were lost during Late Antiquity. In this paper, I would like to add to the debate by introducing the results from my research on the evolution of aqueducts and water supply in the cities of post-Roman Iberia. The evident lack of proper maintenance and structural repairs fits within general patterns of late antique urban transformations such as the declining interest of curiales in public munificence and the crisis of the municipal institution. But added to this we must see a technical and technological disruption between the Roman past and the Visigothic centuries, which becomes evident when compared with the situation in the Umayyad period and parallels similar developments in other technical skills, such as pottery productions. In this context, the aqueduct of Reccopolis stands out as a unique example of brand new hydraulic infrastructure. Considering how unique the circumstances of Reccopolis are (i.e., royal foundation) and the links between the Visigothic monarchy and the Eastern Empire (where engineering skills were preserved), there is also a case to propose the eventual presence of Eastern engineers linked to this main construction project.



Overall, I propose a model in which the lack of demand throughout the fifth and sixth centuries, together with the dismantling of the Imperial state apparatus and the disarticulation of the early Roman municipal system (which favored the construction of aqueducts in the first place) caused a fatal disruption in the transmission of engineering knowledge which, by the period of Visigothic state formation, could only be satisfied by tapping into the active networks of engineering training of the East.

ESSAY

Introduction

Whereas it is difficult for the uninitiated to see engineering as a means of communication (and engineering is used to transmit ideas, such as triumph over nature, superior skills, construction feats, architecture of empire, etc.), the teaching of engineering and the transmission of engineering as a bloc of knowledge is in itself another act of communication. Within this last point of view, teaching can be understood through Communication Theory as having a sender (the educator), a receiver (the student), a message (the scientific knowledge, engineering theory), a channel and a code (the means of transmitting this knowledge), all englobed in a set of circumstances which determine how this knowledge is transmitted. Based on recent archaeological research, I will put forward in this paper that, during late and post-Roman periods of the Iberian Peninsula, the Roman mode of transmitting engineering down the generations was profoundly disturbed. As a result, the theoretical and applied approaches of passing on the knowledge became completely dissociated. The consequences of this were an end of trained engineers as skilled professionals and the abandonment of arched and vaulted structures until the eighth century.

It will be evident to the reader that this proposal is not entirely new, as it derives mostly from the results and postulates of the CSIC school of Luis Caballero, María Ángeles Utrero, and others.¹ It is something which I myself have also worked on for various years, although focusing only on aqueducts and water infrastructure,² and also comparing it with the transmission of medicine.³ Overall, I would like to add to this debate with my own examples (drawn from urban aqueducts), in two different ways: by adding more information partly backing the Caballero argument regarding construction in the Visigothic period, and by underlining the rupture element in the communication of this particular area of knowledge from the Roman past into the Early Medieval West.

The background debate

As mentioned above, this paper fits within an ongoing historiographical debate (which here has to be necessarily summarized to a bare minimum), with one position defending the nineteenth-century Art-Historical dating for a set of rural churches to the late-seventh century (therefore, Visigothic architecture), and the opposing one claiming that they have to be necessarily post-711 and, more likely, ninth century in date.⁴ Whereas the former view supports the idea that vaults and arches were being built (with newly quarried stone) in the second half of the seventh century, the latter

¹ Summarized recently in María Ángeles Utrero Agudo, “The artisans behind Visigothic buildings: the materiality of identity,” *Visigothic Symposium 2: Iberian Spaces, Iberian Identities* (2017): 99-103.

² Javier Martínez Jiménez, *Aqueducts and Water Supply in the Towns of Post-Roman Spain, AD400-1000* (DPhil thesis: University of Oxford, 2014), 178. An updated monograph based on the thesis is being prepared for 2019 for Gorgias Press.

³ Javier Martínez Jiménez and Patricia González Gutiérrez, “Knowledge and specialised trades in the late antique West: Medicine vs Engineering,” *Journal of Late Antique Religion and Culture* 11 (2017): 38-58.

⁴ José Carlos Sánchez Pardo, Rebeca Blanco Rotea and Jorge Sanjurjo Sánchez, “The church of Santa Comba de Bande and early medieval Iberian architecture: new chronological results,” *Antiquity* 91.358, 1011-26; Utrero Agudo, “artisans”; Alberto León, “Se non è vero, è sempre ben trovato? a vueltas con la arquitectura civil tardoantigua y altomedieval hispana,” in *Alla ricerca di un passato complesso. Contributi in onore di Gian Pietro Brogiolo per il suo settantesimo compleanno*, ed. Alexandra Chavarria and Miljenko Jurković (Zagreb: Motovun, 2016), 175-99; Rose Walker, *Art in Spain and Portugal from the Romans to the Early Middle Ages. Late Antique and Early Medieval Iberia 1* (Amsterdam: Amsterdam University Press, 2016).

underlines the fact that all the excavated churches dated archaeologically to that period are simple aisled structures with no structural evidence for either vaults or arches. Furthermore, the “Visigothic” dating derives of the first argument entirely from the presence of Recceswinth’s (r. 649-672) inscription at the church of Saint John at Baños, and then drawing stylistic parallels from this one to all others – an inscription which is oddly located in the church, alongside with mismatched reused material (and an inscription which might even itself be a copy).⁵ Attempts to date these buildings based on presumed historical circumstances fail to be convincing, as they become circular arguments which project concepts of territorial control to these churches based on assumptions which derive from acknowledging these churches as Visigothic in the first place.⁶ The debate is still ongoing, and this article is not the place to find a solution.

One of the key questions of this discussion is, as I have said, arches and vaulting, and it is there where hydraulic engineering comes in, because Roman aqueducts and water-consuming structures relied greatly on vaulting and arching. In fact, it is widely accepted that the Romans achieved wonderful feats of domed and vaulted engineering, such as [Hadrian’s] Agrippa’s Pantheon, the Great Hall of the Markets of Trajan, or the Basilica of Maxentius (fig. 1).⁷ Aqueducts are much more widespread across the Empire than those other imperially-sponsored mega-structures, so they may serve as a good indicator of the spread of Roman engineering techniques. But similarly, even if they are not large domed buildings, they do rely on very precise calculations: the water flow is regulated by means of the incredibly gentle and

⁵ Walker, *Art in Spain and Portugal*, 134.

⁶ Alexandra Chavarría Arnau, “Churches and aristocracies in seventh-century Spain: some thoughts on the debate on Visigothic churches,” *Early Medieval Europe* 18.2 (2010): 160-74.

⁷ Jean-Pierre Adam, *Roman Building; Materials and Techniques* (London: Routledge, 1994).

constant gradients achieved in the *specus*.⁸ In many cases, these gradients were kept even across long distances; the aqueduct of Constantinople was over 550km long, dwarfing those from Rome or Carthage.⁹ When necessary, pressurized conduits (inverted siphons) were built crossing valleys, rivers and, as in Cádiz, even across the bottom of the sea.¹⁰ These were engineering wonders, built using wooden and brass instruments (*chorobates*, *gromma*), without lenses or optical aids. It may seem unfair to set these examples as a baseline for Visigothic-period engineering, but that is exactly the point: under the imperial system it was possible to carry out these massive and impressive structures, something which was impossible in the post-Roman period.

When looking at the evolution of Roman aqueducts in the post-Roman period from a technical point of view, it is clear that there was a loss of technical knowledge, which partly explains their ultimate abandonment.

Aqueducts in Hispania

There were over 70 aqueducts in Roman Spain, some built in the Augustan period as part of the colonization effort, but the vast majority were built in the Flavian and Trajanic periods, especially as the result of the extension of municipal rights to the Spanish provinces by Vespasian (r. 69-79).¹¹ The expansion of Roman/Italic civic bathing and energetic patterns prompted the demand for aqueducts, even in sites which otherwise would be difficult to define as towns. Of these 70-odd, there is

⁸ Trevor Hodge, *Roman aqueducts and Water Supply* (London: Duckworth, 1992).

⁹ Hodge, *Roman aqueducts*, 346; Jim Crow, Jonathan Bardill and Richard Bayliss, *The Water Supply of Byzantine Constantinople*. Journal of Roman Studies Monograph 11 (London: Society for the Promotion of Roman studies, 2008).

¹⁰ Hodge, *Roman aqueducts*.

¹¹ Javier Martínez Jiménez, “*Tantum pecuniam male perdiderunt*: Aqueducts and municipal investment in Hispania,” in *Signos de debilidad y crisis en las ciudades occidentales del Imperio Romano (I-III d. C.)*, ed. Javier Andreu and Aitor Blanco (Pamplona: University of Navarre, in press).

evidence for only a few being in use by the beginning of the fifth century (Almuñécar, Barcelona, Braga, Conimbriga, two in Córdoba, Lisbon, Lugo, three in Mérida, Segovia, Seville, Tarazona, two in Tarragona, Valencia, Zaragoza).¹² These seventeen fell down to three or four by AD 711 – and out of those one was the new aqueduct built at *Reccopolis*.

This decline (fig. 2) has a first steep phase during the late third and fourth centuries, which is when most of the aqueducts went out of use. These aqueducts belonged to towns which after the administrative reforms of the Tetrarchy were relegated to a secondary or tertiary status, when not completely abandoned as urban centres (e.g., Toledo, Los Bañales, Ucubi, Uxama, Peñafior, Cádiz, etc.). The second, flatter section of the graph corresponds to those cities which remained important administrative or economic centres, where the local elites and the town councils still had the will or the resources to keep up with the maintenance of the aqueducts. For these, the preservation of the aqueduct was simply a matter of attrition, although in some cases as in Segovia the continuity might have been linked to other particular technical characteristics.¹³

One trend which underlines the graph is that from the third century onwards there were very few attempts to actively repair aqueducts. That is not to say that there was no basic maintenance (cleaning, de-clogging, etc.) as this explains the long-term continuity, but there were no major repairs or reconstructions after *vis major* damage. The aqueducts of Baelo Claudia or the Aqua Augusta of Córdoba were damaged by earthquakes during the third and fourth centuries, but were not repaired or put back

¹² This is just a numeric summary – for the methodology, caveats, and problems see Martínez Jiménez, *Aqueducts and Water Supply*.

¹³ Elena Sánchez López and Javier Martínez Jiménez, *Los acueductos de Hispania: Construcción y abandono*. Colección Juanelo Turriano de Historia de la Ingeniería (Madrid: Fundación Juanelo Turriano, 2016), 135-41.

into use (fig. 3). At that stage we know that the technical knowledge to build and repair aqueducts existed in Spain (other Hispanic aqueducts were built during the third century), but there was a lack of interest or of resources to rebuild heavily damaged ones.¹⁴

This lack of new aqueduct construction was only reversed in the late sixth century. In this moment, during the Visigothic period of state formation,¹⁵ the redefinition of the roles and ranks of the urban elites, together with the new administrative system, prompted a new phase of urban construction. Aqueducts continued to be monumental markers of prestige, much in the way they had done in the Roman period. Furthermore, as the number of functioning aqueducts decreased, the few still in use became more unique and prestigious. In the Eastern Empire and Ostrogothic Italy aqueduct construction, especially with royal/imperial patronage, was not unusual (in fact, even from the fifth century onwards only these large, powerful donors seem to have carried out aqueduct repairs/building).¹⁶ But in Visigothic Spain this proved trickier.

In fact, there are only two Visigothic aqueduct-related construction projects. The first one is the failed attempt at rebuilding a section of the Proserpina aqueduct in Mérida (fig. 4). This project has left only partial evidence. This reconstruction is assumed to have happened mostly from the oddly built pillar at the beginning of the *arcuatio* over the Albarregas river. This pillar is built in a construction technique which mirrors that

¹⁴ Which underlines the issue of how necessary they really were for urban life.

¹⁵ Lauro Olmo Enciso, “The royal foundation of Recópolis and the urban renewal in Iberia during the second half of the sixth century,” in *Post-Roman Towns and Trade in Europe and Byzantium*, ed. Joachim Henning (Berlin: DeGruyter, 2007), 181-99.

¹⁶ Yuri Marano, “Watered... with the Life-Giving Wave’. Aqueducts and Water Management in Ostrogothic Italy,” in *Ownership and Exploitation of Land and Natural Resources in the Roman World*, ed. Paul Erdkamp, Koenraad Verboven, Arjan Zuiderhoek (Oxford: Oxford University Press, 2015), 150-69; Jordan Pickett, “Water and Empire in the *De Aedificiis* of Procopius,” *Dumbarton Oaks Papers* 71 (2017): 84-125.

of other Visigothic buildings of Mérida,¹⁷ and stands between a *castellum aquarum* (settling tank) and the rest of the arcade. The pillar even imitates the Roman construction technique, alternating brick and ashlar, although without the added side-buttresses. It is, furthermore, slightly twisted on its axis, and slightly leaning off the vertical – although it is difficult to say if this deviation dates back to the original construction or to later damage. However, there is no evidence to support that the arches were ever added to link with the upstream or downstream *specus*. The lack of piped-water consuming structures dated for the Visigothic period from inside the city further suggests that this project was never successfully concluded.

The other project is the aqueduct of Reccopolis.¹⁸ The city, an *ex novo* foundation of the late sixth century was a royal centre, with a palatine complex, walls, a church, suburbs, and a street system.¹⁹ In its territory there are remains of an aqueduct over 2.5km long, diverting water from a near stream which had to be necessarily leading towards the new city. The construction technique of the city and the aqueduct match, which further confirms the link between both and the aqueduct's chronology. This aqueduct is, however (like the whole site of Reccopolis), a single, unique example; an outlier, which contradicts all the other patterns visible in other aqueducts in the peninsula. It is so unique that it raises the issue that the engineers may have come from abroad. In fact, it is certainly with foreign intervention that we see long-distance urban water supply systems being built again in the Iberian Peninsula, during the Umayyad period.

¹⁷ Personal communication with Miguel Alba Calzado, from the Consorcio de Mérida. Cf. Martínez Jiménez, *Aqueducts and Water Supply*, 178.

¹⁸ Javier Martínez Jiménez, "A preliminary study of the aqueduct of Reccopolis," *Oxford Journal of Archaeology* 34.4 (2015), 301-20.

¹⁹ Olmo Enciso, "The royal foundation of Recópolis."

Theory v. practice: Some explanations?

Going back to communication and teaching, the key to understanding this evolution in the attitude towards aqueduct repairs and failed construction may be simply that they did not know how to build them. The underlining principle behind this assertion could be the rupture in the chains of transmission of knowledge; the discontinuity of communications and teaching as they had developed within a very specific system during the early Roman period.

It would be futile to deny that there were no skilled builders at all in the post-Roman period,²⁰ otherwise none of the monuments under consideration would have been built. But there is an evident lack of trained architects and engineers, who were all too common in the imperial period, as Pliny is reminded by Trajan;²¹ people who could calculate the distribution of loads on a vault, who could level the course of an aqueduct, or who could calculate volumes of water discharge and inflow.

In the early Roman period, there were two characteristic chains of transmission of knowledge in the training of engineers and architects: the first one was through the army, and the other one through private apprenticeships. Both relied on the personal transmission of information, although if any reference handbooks existed on the topic, none has come down to us. This already highlights how engineering training was linked to the state in a stable but fragile back-feeding loop, as it generated both the demand (military engineering, large construction projects) and the supply (by

²⁰ Utrero Agudo, “artisans”; cf. with the “vernacular builders” mentioned in Luke Lavan, “Explaining technological change: innovation, stagnation, recession and replacement,” in *Technology in Transition. AD 300-650. Late Antique Archaeology 4*, ed. Luke Lavan, Enrico Zanini and Alexander Sarantis (Leiden: Brill, 2008), xv-xl.

²¹ *Epist. X. 40: Nulla provincia est, quae non peritos et ingeniosos homines habeat* – “There is no province which lacks skilled and clever men.” For an edition of Pliny the Younger’s letters see: *Epistularum Libri Decem*, ed. Roger Mynors (Oxford: Clarendon Press, 1963). For a translation see *The Letters of the Younger Pliny*, trans. Betty Radice (NY: Penguin, 1969).

training), even if its benefits trickled down to provincial cities. The private initiative was largely fed from this system, as local elites, once integrated within the Roman model, demanded their own complex buildings (theatres, aqueducts, circuses, etc.). As a result, once the Empire collapsed in the West, the army disbanded, shutting down one avenue of training (*foederati* troops were not trained in military engineering). Similarly, large construction projects were already rare in the late fourth century, and quite limited to central places linked to imperial elites, decreasing the demand for specifically trained engineers. By the end of the fifth century, it seems clear that there were no incentives to preserve any training in structural engineering. By the late sixth century, when new construction projects start again (linked to the process of Visigothic state formation), the gap back to the last moment when new engineers were still in training was wide enough to reduce the probabilities of their existence to the minimum (especially when looking at the archaeological evidence).²² Furthermore, it is difficult to imagine specialized technical levelling and measuring equipment surviving without the associated workmen trained in them.²³

Despite this, there had been from the early Roman period an elite tradition of architectural discussion. A minimal knowledge of architecture was seen as part of the body of knowledge a Roman aristocrat needed, even if only because they may be involved in construction projects as part of their *cursus honorum*. Even at a much later date Pope Gregory (590-604) shows a similar politically-minded approach to construction.²⁴ It is in this elite context that we should fit the only work on building we have from the Classical period: Vitruvius's *De Architectura*. It would be wrong to see this as a handbook for training new architects (as opposed to the many handbooks

²² Martínez and Gutiérrez, "Knowledge and specialised trades in the late antique West."

²³ Hodge, *Roman aqueducts*, 197-207; Utrero Agudo, "artisans," 107.

²⁴ Gregory the Great, *Reg. Epis.* 5.53. For an edition see *Gregorii I Papae, Registrum Epistolarum*, ed. Paul Ewald and Ludwig Hartmann, *MGH* (Berlin: Weidmann, 1891).

which existed for grammar or medicine students), as it fits better in a theoretical approach to the matter; a learned guide for aristocrats, but not a teaching manual. In late antiquity, the theoretical approach to the monumental past, the appreciation of old monuments, fits in this academic and self-contained elite study of engineering. Epigrams of Vitruvius (and of Frontinus's *De Aquis*) may have been available to Isidore of Seville (560-636), as is evident in his descriptions of columns, arches and water pipes.²⁵ Even later, similar discussions are known by Alcuin (735-804)²⁶ and Einhard (775-840),²⁷ in a tradition that would continue until Vitruvius was 're-discovered' in the Renaissance and not only theoretically studied, but also practically applied.

The situation was different in the Roman East, where the army continued to exist and there were imperial and civic construction projects which required complex engineering (including Saint Sophia in Constantinople, but also many aqueducts²⁸). The apparent monopoly over this technical knowledge was recognized beyond the Empire, and it was not unusual to find rulers asking for specialized builders during the sixth and seventh centuries for their own local projects. We know of Avar, Ostrogothic and Papal examples for this,²⁹ so it would not be surprising if the Visigoths had done the same (especially in the context of the aqueduct of Reccopolis).³⁰ This continuity of eastern Roman engineering enabled the development of Umayyad Syrian architecture after the Islamic conquest, including arcaded and vaulted buildings such as the Great Mosque of Damascus, the Dome of the Rock, and

²⁵ Isidore of Seville, *Etym.* 15.8.9-17. For an edition see *Isidori Hispalensis Episcopi Etymologiarum sive Originum Libri XX*, ed. W. M. Lindsay, Oxford, 1911; and for a translation: *The Etymologies of Isidore of Seville*, trans. Stephen A. Barney, W. J. Lewish, J. A Beach and Oliver Berghof (Cambridge: Cambridge University Press, 2006).

²⁶ Alcuin, *Epist.* 308. For an edition see *Epistolae*, ed. Ernst Dümmler, *MGH* (Berlin: Weidmann, 1895).

²⁷ Einhard, *Epist.* 57. For an edition see *Epistolae*, ed. K. Hampe, *MGH, Epp.* 5 (Berlin, 1898-1899).

²⁸ Pickett, "Water and Empire."

²⁹ Martínez and Gutiérrez, "Knowledge and specialised trades in the late antique West."

³⁰ Martínez Jiménez, "A preliminary study."

the al-Aqsa mosque of Jerusalem.³¹ The Umayyads were, furthermore, also involved in the construction of aqueducts in the Roman fashion.³² From Syria (and acknowledging this as an intrinsically diffusionist argument), these complex engineering techniques were reintroduced in the Iberian Peninsula, together with other ‘lost’ Roman technologies such as fast-wheel pottery, pottery glazing or ashlar cutting.³³

Considering these circumstances, the communication of knowledge and the preservation of engineering skills was very closely linked to state control, even if it existed outside it as a scholarly topic (and not a practical science) amongst the elites. In the Western and Eastern Roman examples, civilian and military engineers coexisted side by side, and benefited from a complex training system, something which was partially taken in the Umayyad sphere.³⁴ But in the Visigothic period there was not a state-related system which promoted training in engineering, and the gap with the active Roman past was such that the teaching and apprenticeships had broken down. There was still, however, a strong horizontal level of communication at an elite level (preservation of a scholarly approach to architecture), and a continuing tradition of masonry building.

³¹ Robert Hillenbrand, *Islamic Architecture* (Edinburgh: Edinburgh University Press 2000 [1994]), 68-73.

³² Both in newly built cities, such as Ramla, or old ones. Cf. Nimrod Luz, “The construction of an Islamic city in Palestine. The case of Umayyad al-Ramla,” *Journal of the Royal Society of Asiatic Studies* 71 (1997): 27-52; Amir Gorzalczany, “The Umayyad aqueduct to Ramla and other finds near Kibutz Na’an,” *Atiqot* 68 (2011): 1-27; Yosi Porath, “Hydraulic plaster in aqueducts as a chronological indicator,” in *The Aqueducts of Israel*. Journal of Roman Archaeology Supplement Series 46, ed. David Amit, Joseph Patrich and Yizhar Hirschfeld (Ann Arbor: Journal of Roman Archaeology, 2002), 25-36.

³³ Utrero Agudo, “artisans”; Miguel Alba Calzado and Sonia Gutiérrez Lloret, “Las producciones de transición al Mundo Islámico: el problema de la cerámica paleoandalusí (siglos VIII y IX),” in *Cerámicas hispanorromanas: un estado de la cuestión*, ed. Darío Bernal Casasola and Albert Ribera Lacomba (Cádiz: University of Cádiz, 2008), 585-613.

³⁴ It would be incredibly interesting to explore the literary and scholar Umayyad traditions in engineering, but this goes beyond the scope of the current paper.

Conclusions

Communication and interaction can be seen from many different perspectives, and it is easy to forget that one of the main purposes of communication is to transfer knowledge, not only horizontally amongst coevals, but also vertically, down in time, preserving knowledge for future generations. In this sense, there are very few cases where communication, miscommunication, and end of communication are as evident in the archaeological record as the end of the teaching of engineering in late antique Spain. This does not mean that the seventh century was ‘empty’ of monuments, but simply that it was not possible to build vaults, arches or aqueducts in the Roman way, while other equally functional (but perhaps less complex and elegant) solutions were used.

Overall, what I have put forward in this necessarily short article are different ways in which transmission of knowledge was cut short, as exemplified by the evolution of aqueducts in the Iberian Peninsula. First, there was a rupture of communications in terms of teaching after the imperial system collapsed. Second (and in parallel), there was an end to the demand for such specialized knowledge. Third, when this demand appeared again, the rupture of the chains of transmission had been fatal, so it was necessary to look into other networks of knowledge where this had not happened. Lastly, it was only after the re-integration of the peninsula into a polity where this system still existed that specialized structural engineering was reintroduced.

List of figures



Figure 1: The Pantheon in Rome, with its concrete dome and brick rotunda, is one of the feats of Roman engineering (photo by the author).

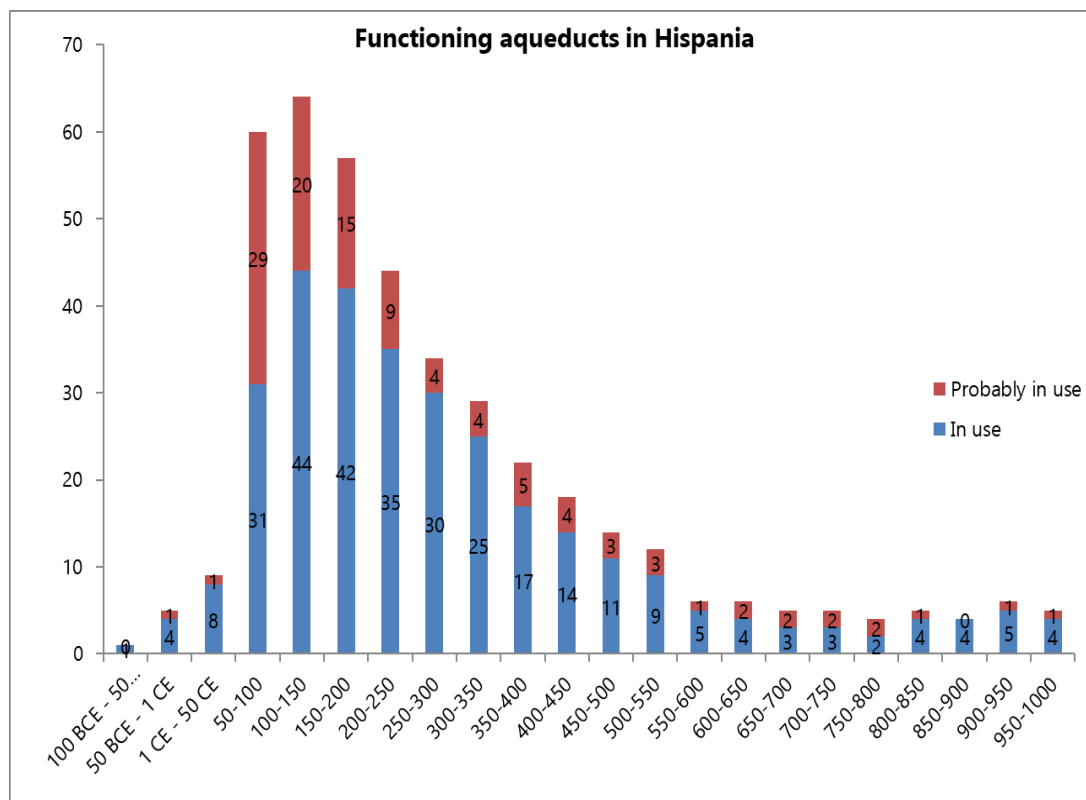


Figure 2: Graph showing the evolution of the number of functioning aqueducts through time in the Iberian Peninsula (by the author).



Figure 3: Broken remains of one of the aqueducts of Baelo Claudia (Cádiz), damaged by an earthquake in the third century and never repaired (photo by Elena Sánchez).



Figure 4: Visigothic repaired pillar from the Proserpina/Los Milagros aqueduct in Mérida (photo by the author).

Bibliography

Primary

Alcuin. *Epistolae*. Edited by Ernst Dümmler, *MGH*. Berlin: Weidmann, 1895.

Einhard. *Epistolae*. Edited by K. Hampe, *MGH, Epp. 5*. Berlin, 1898-1899.

Gregory the Great. *Gregorii I Papae, Registrum Epistolarum*. Edited by Paul Ewald and Ludwig Hartmann, *MGH*. Berlin: Weidmann, 1891.

Isidore of Seville. *Origines, or, Etymologies*. Edited by W. M. Lindsay, *Isidori Hispalensis Episcopi Etymologiarum sive Originum Libri XX*. Oxford, 1911; *The Etymologies of Isidore of Seville*. Translated by Stephen A. Barney, W. J. Lewis, J. A. Beach and Oliver Berghof. Cambridge: Cambridge University Press, 2006.

Pliny the Younger. *Epistularum Libri Decem*. Edited by Roger Mynors. Oxford: Clarendon Press, 1963; Translated by Betty Radice, *The Letters of the Younger Pliny*. NY: Penguin, 1969.

Secondary

Adam, Jean-Pierre. *Roman Building. Materials and Techniques*. London: Batsford, 1994 [1989].

Alba Calzado, Miguel, and Sonia Gutiérrez Lloret. “Las producciones de transición al Mundo Islámico: el problema de la cerámica paleoandalusí (siglos VIII y IX).” In *Cerámicas hispanorromanas: un estado de la cuestión*, edited by Darío Bernal Casasola, & Albert Ribera Lacomba, 585-613. Cádiz: University of Cádiz, 2008.

Chavarría Arnau, Alexandra. “Churches and Aristocracies in seventh-century Spain: Some Thoughts on the Debate on Visigothic Churches.” *Early Medieval Europe* 18.2 (2010): 160-74.

Crow, Jim, Jonathan Bardill, and Richard Bayliss. *The Water Supply of Byzantine Constantinople. JRS Monograph 11*. London: The Roman Society, 2008.

Gorzalczany, Amir. “The Umayyad Aqueduct to Ramla and other Finds near Kibutz Na’an.” *Atiqot* 68 (2011): 1-27.

Hillenbrand, Robert. *Islamic Architecture*. Edinburgh: Edinburgh University Press, 2000 [1994].

Hodge, Trevor. *Roman Aqueducts and Water Supply*. London: Duckworth, 1992.

Lavan, Luke. “Explaining Technological Change: Innovation, Stagnation, Recession and Replacement.” In *Technology in Transition. AD 300-650. Late Antique Archaeology 4*, edited by Luke Lavan, Enrico Zanini, & Alexander Sarantis, xv-xl. Leiden: Brill, 2008.

León, Alberto. “Se non è vero, è sempre ben trovato? a vueltas con la arquitectura civil tardoantigua y altomedieval hispana.” In *Alla ricerca di un passato complesso. Contributi in onore di Gian Pietro Brogiolo per il suo settantesimo compleanno*,

edited by Alexandra Chavarría, & Miljenko Jurković, 175-99. Zagreb: Motovun, 2016.

Luz, Nimrod. "The Construction of an Islamic City in Palestine. The Case of Umayyad al-Ramla." *Journal of the Royal Society of Asiatic Studies* 71 (1997): 27-52.

Marano, Yuri. "'Watered... with the Life-Giving Wave'. Aqueducts and Water Management in Ostrogothic Italy." In *Ownership and Exploitation of Land and Natural Resources in the Roman World*, edited by Paul Erdkamp, Koenraad Verboven, and Arjan Zuiderhoek, 150-69. Oxford: Oxford University Press, 2015.

Martínez Jiménez, Javier. *Aqueducts and Water Supply in the Towns of Post-Roman Spain, AD400-1000*. DPhil thesis, University of Oxford, 2014.

Martínez Jiménez, Javier. "A Preliminary Study on the Aqueduct of Reccopolis." *Oxford Journal of Archaeology* 34.3 (2015): 301-20.

Martínez Jiménez, Javier, and Patricia González Gutiérrez. "Knowledge and Specialised Trades in the Late Antique West: Medicine vs. Engineering." *Journal for Late Antique Religion and Culture* 11 (2017): 38-58.

Martínez Jiménez, Javier. "Tantum pecuniam male perdiderunt: aqueducts and municipal investment in Hispania." In *Signos de debilidad y crisis en las ciudades occidentales del Imperio Romano (I-III d. C.)*, edited by Javier Andreu Pintado, and Aitor Blanco Pérez. Pamplona: University of Navarre, in press.

Olmo Enciso, Lauro. "The Royal Foundation of Recópolis and the Urban Renewal in Iberia during the second half of the sixth century." In *Post-Roman Towns and Trade in Europe and Byzantium*, edited by Joachim Henning, 181-99. Berlin: DeGruyter, 2007.

Pickett, Jordan. "Water and Empire in the de Aedificiis of Procopius." *Dumbarton Oaks Papers* 71 (2017): 95-125.

Porath, Yosi. "Hydraulic Plaster in Aqueducts as a Chronological Indicator." In *The Aqueducts of Israel. JRA Supplement Series 46*, edited by Davis Amit, Patrich, Joseph, & Yizhar Hirschfeld, 25-36. Portsmouth: JRA, 2002.

Sánchez López, Elena, and Javier Martínez Jiménez. *Los acueductos de Hispania. Construcción y abandono*. Madrid: Fundación Juanelo Turriano, 2016.

Sánchez Pardo, José Carlos, Rebeca Blanco Rotea, and Jorge Sanjurjo Sánchez. "The Church of Santa Comba de Bande and Early Medieval Iberian Architecture: New Chronological Results." *Antiquity* 91.358 (2017): 1011-26.

Utrero Agudo, María Ángeles. "The Artisans behind Visigothic Buildings: The Materiality of Identity," *Visigothic Symposium 2: Iberian Spaces, Iberian Identities* (2017): 99-103.

Walker, Rose. *Art in Spain and Portugal from the Romans to the Early Middle Ages. Late Antique and Early Medieval Iberia 1*. Amsterdam: Amsterdam University Press, 2016.