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INTRODUCTION

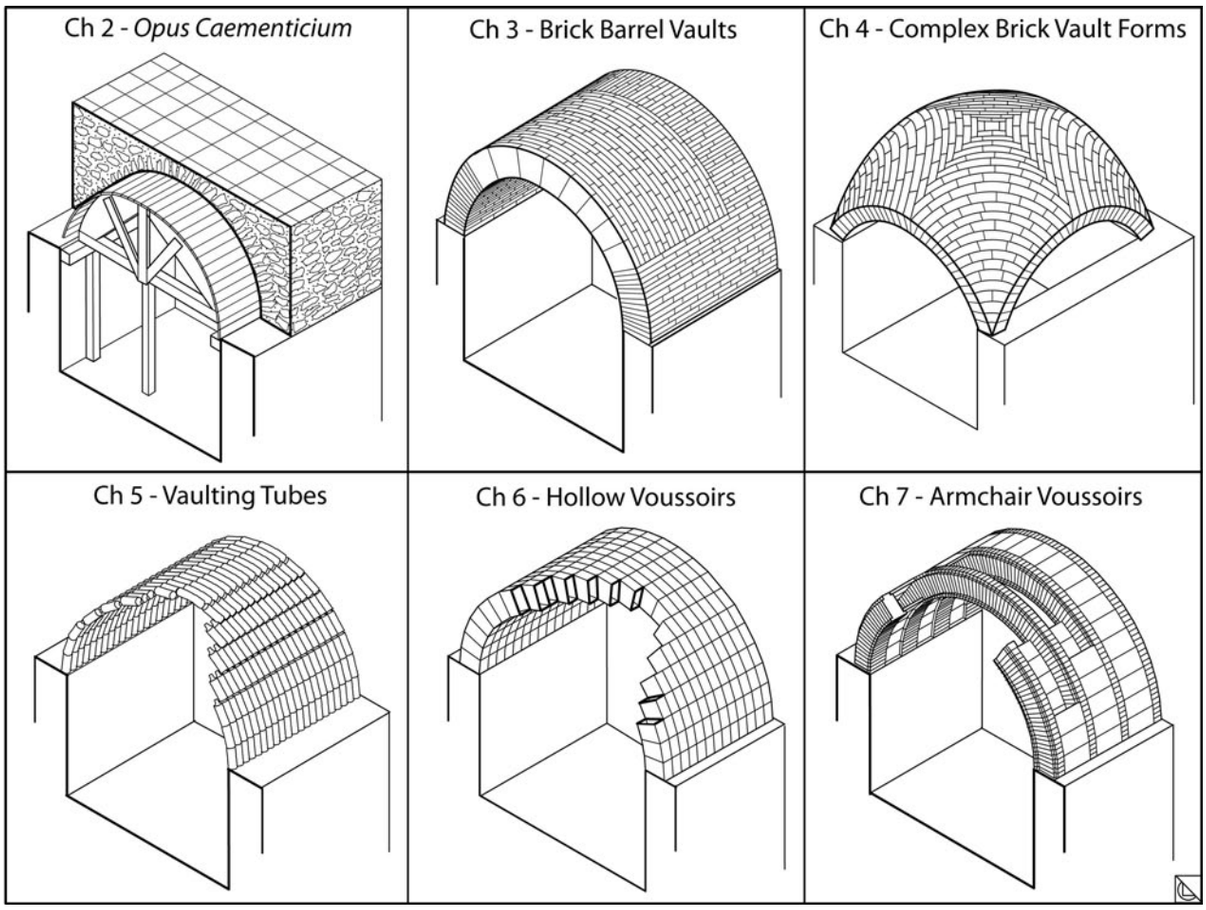
The impressive vaulted structures of ancient Rome have been seen as the embodiment of the power of the Roman Empire, whereas the vaulted structures scattered throughout the provinces of that empire have attracted less attention. They have typically been regarded as smaller, lesser imitations of the greatness exemplified by those in Rome itself. Even the term – provincial architecture – brings with it connotations of inferiority, subservience, and mediocrity. This mindset that privileges the center over the periphery shaped the way in which Roman architecture, particularly construction technology, was studied during the twentieth century. From a sociopolitical perspective, the architecture of the Roman provinces has often been presented as a result of the local patrons and builders adopting forms and methods developed in the imperial capital as a means of emulating those in power; however, as more recent scholarship emphasizes, the reality is much more complex.

My focus is on the originality of the vaulting techniques used in structures throughout the Roman Empire. The techniques examined in this study were often unknown in the capital, and their development was the result of a web of factors that differed from region to region. Certainly the imperial system was the loom on which the web was woven, but the innovative results were the inspiration of individuals who were responding to local conditions – social connections, economic pressures, and political realities. By examining a specific set of vaulting techniques, I try to unravel some of the threads that affected their creation and dissemination.

HOW TO USE THIS BOOK

The book is organized so it can be used by both general readers and specialists. Each chapter provides a brief introduction to the major issues and a conclusion that includes an overview and assessment of the material discussed. A general reader can read the first and last chapters of the book, as well as the beginning and end of each chapter, to get an idea of the issues discussed and their relevance, whereas the specialist can delve into the details of the arguments presented within the chapters. Chapters 2–7 each begins with a drawing of the technique being studied, which is then followed by a distribution map of all the locations where that technique occurs. Each distribution map has a corresponding

Catalogs (WebCat.) and color figures (WebFig.) can be downloaded at www.cambridge.org/vaulting



1. Illustrations of the six techniques under examination.

database of all the examples, noted as a Web Catalog, which can be downloaded from the Cambridge University Press website (www.cambridge.org/vaulting). Some of the Excel files making up the Web Catalogs contain more than one sheet, in which case the sheets are labeled A, B, C, etc. So, "WebCat. 5-B" refers to sheet B within the Excel file called WebCat. 5. In the text, I only discuss examples of a technique that illustrate the particular points I make. For those who want to pursue the subject further, details and bibliographical references for each entry on the distribution maps are included in the Web Catalogs. A separate bibliography for the references in the databases is provided as a downloadable pdf file. Supplemental color illustrations, Web Figures, can be downloaded as pdf files and are designated in the text as WebFig. 1, WebFig. 2, and so on.

GOALS AND INTENTIONS

The study is organized around a group of innovative vaulting techniques chosen because they facilitated the building process, improved the structural behavior of the building, or improved the function of the building in a manner that benefited the user (Fig. 1). In some cases, they provided more than one of these advantages, and the reasons for their use could change over time. Each of the techniques

2. Column of the Temple of Aphrodite, Aphrodisias, with dedication inscription by Eumachus Diogenes and his wife Ammias Olympias (late first century BCE to early first century CE) (photo: Philip Stinson).

tells a story of its own and provides insight into broader issues, such as the relationship between various types of technologies (construction, agriculture, pottery), the effect of trade networks and military movements on technology transfer, and the role of the imperial administration in promulgating technological change. I do not deal with innovative new vault forms unless the shape was inherently generated by the construction technique being studied. Moreover, the study is *not* intended as a survey of vaulted construction throughout the Roman Empire; rather, it uses a defined set of vaulting techniques as a means of looking at larger questions of technological development.

My intention is to document this group of vaulting techniques in order to identify cultural factors that

influenced why they developed when and where they did and to determine why they spread to particular areas and not to others. In other words, I use the chosen vaulting techniques as vehicles for tracing technology transfer over time, and I relate them to changing political and economic conditions. By focusing on the individual building elements and materials of vaulted structures, I place the emphasis on process rather than product – I examine the factors leading to the constructional choices made by builders and their patrons and how the choices differed between regions and over time. The geographical scope of the project is defined by where the techniques were used. The chronological scope is from the beginning of the imperial period under Augustus to the reign of Constantine, when his embrace of Christianity brought about a shift in the power structure that affected the allocation of resources to building projects. Some of the techniques continue beyond the fourth century, but I intend to deal with this later material (fourth to sixth centuries CE) in a subsequent work that will also revisit late antique vaulting in Rome and Italy after the capital moved to Constantinople.

METHOD AND APPROACH

I have sometimes been asked, "What is your method – inductive or deductive?" Thinking about this question, I realized that I oscillate between the two modes of reasoning. The beginnings of this project were inductive in that I started with the specifics and worked toward a general explanation by collecting as many examples of each technique as I could find and then examining the data using a spreadsheet and a GIS map to help form hypotheses that could explain the phenomena represented by the data. I then shifted to the deductive approach and tested these hypotheses by searching for additional material (historical, epigraphical, archaeological) that could support or reject the hypotheses. During the twentieth century, deductive approaches (i.e., starting with a general hypothesis) often led to the neglect of relevant evidence that could have challenged the original hypothesis. I realize that the results presented here may well change when new information comes to light, but I hope that at a minimum this study serves to reframe the questions being asked about the role of building technology in the provinces and to provide a body of evidence that can be enhanced in the future to refine the questions even further.

As a framework for developing the hypotheses, I adopted a definition of technological development cited by K. Greene, which identifies three phases: (1) *invention/discovery*, (2) *innovation*, and (3) *diffusion/technology transfer*.[1] Invention is defined as the act of implementing an original idea in a new device or process, whereas innovation is the process by which the invention is brought into use.[2] Pinpointing an invention is difficult in the ancient world, and it may represent the eureka moment or chance discovery of an otherwise unidentified craftsperson. The innovation phase is often more informative because it reveals more about the broader context. This phase can also be understood in terms of four factors: (1) *accumulated knowledge*, (2) *evident need*, (3) *economic ability*, and (4) *social acceptability*.[3] The third phase of technological development includes diffusion, the process by which an innovation is spread within society, and with it technology transfer – the spread of skills, knowledge, and processes from one area to another. Both provide insight into the motivating social, economic, and political forces within society.

I found that these three phases frequently coincided quite closely with my assembled data. For example, the idea for a technique might result in an invention quite early, but the innovation that allowed it to be used on a wider scale occurred much later and in a different place when the four influencing factors cited earlier came together to create the appropriate context. Then once the innovation was

spread to other areas of the empire (diffusion), it often changed in small ways to respond to different conditions. Another useful concept emphasized by Greene is the *technology shelf*, which refers to the range of technological choices, both materials and processes, available in a particular time and place to respond to specific circumstances.[4] The establishment of the Roman Empire dramatically increased the technological choices available to patrons, architects, and builders, so when we see a particular vaulting technique, its use usually represents only one of many options. The technology shelf reminds us that technological determinism rarely explains the whole picture; human choice was also at work. Choice was affected by a myriad of factors (personal alliances, economic constraints, and social pressures) that may not have even been clear to the person making the choice, much less to the present-day archaeologist trying to interpret the fragmentary evidence. The technology shelf thus helps define the context within which the individuals involved in a project were working. As we see, the shelf was broad, but its contents varied throughout the empire.

This project is dependent on nineteenth- and twentieth-century studies of construction in the Roman provinces, particularly by A. Choisy (fl. 1870–1900) and J. B. Ward-Perkins (fl. 1950–80),[5] as well as on more recent work by scholars such as J. P. Adam, H. Dodge, and F. Yegül.[6] In addition, I refer to numerous studies that focus on individual techniques in particular regions. The creation of the databases on which this study is based would not have been possible without the careful observations and documentation published by other scholars. Many of these more detailed studies on individual techniques occurred during the 1980s and 1990s: for example, G. Brodribb on hollow voussoirs (1983, 1987); S. Storz (1994) and R. J. A. Wilson (1992) on vaulting tubes; A. Bouet (1999), M. Fincker (1986), and A. Torrecilla Aznar (1999) on armchair voussoirs. Likewise, excavation and survey work at many sites has yielded and continues to produce new information. Thus, since the time of Choisy and Ward-Perkins, the nature of the evidence has changed dramatically, and much of it has not yet been synthesized.

The approach to ancient technology has shifted greatly since the major works on building construction were written. The study of ancient technology has typically been linked to studies of the economy. During the twentieth century the dominant theory was the primitivist view, most notably that of M. I. Finley, whereby ancient technology was seen as stagnant due to the reliance on slave labor and the inherent cultural disdain for its practical applications.[7] Building construction in particular was not seen as relevant. In fact, H. Hodges's *Technology in the Ancient World* (1970) and J. G. Landels' *Engineering in the Ancient World* (1978)[8] did not include building technology at all. Recent approaches to the Roman economy advocate for a more complex view in which technological advances play a much greater role than acknowledged previously,[9] and the strictly positivistic approach to ancient construction technology as a how-to manual is moving to a more holistic approach that looks at the building industry as a branch of a larger economic entity. J. DeLaine's work, *The Baths of Caracalla: A Study in the Design, Construction, and Economics of Large-Scale Building Projects in Imperial Rome* (1997), has influenced attitudes by examining the building process step by step and presenting a methodology for quantifying the level of economic stimulus provided by the construction of such a large project.[10] The renewed interest in building technology among archaeologists is exemplified by a series of five international conferences, "Arqueología de la construcción" (Mérida 2007, Siena 2008, Paris 2009, Padua 2012, Oxford 2015).[11]

More generally, the changes in attitudes toward the study of cultural dynamics in the provinces can be seen in the debates over the definition of

Romanization, a term coined in the early twentieth century. The British scholar F. Haverfield put forth the original view of Romanization during the time of British imperialism.[12] It referred to the spread of Roman culture to conquered peoples and implied a one-sided influence – the values of the conquerors imposed on the conquered. The ancient passage most often cited to support this view is Tacitus's description of the contributions of his father-in-law Agricola as the governor of Britannia:

> By private encouragement he [Agricola] set about persuading men who were scattered, uncultured and thus easily aroused to warfare, to become peaceable and accustomed to pleasures offered by leisure. In public he assisted them to build temples, fora, and residences, praising those who were quick to follow his advice and criticizing those who were slow. A competition for honor thus took the place of compulsion . . . and by stages they were led on to the more acceptable vices, public arcades, bath houses and the sophistication of banquets. In their inexperience they took this for *humanitas* when in fact it was part of their slavery.[13]

At a time when ancient texts were prioritized over archaeological evidence, the scholarly ethos during the early twentieth century easily incorporated Tacitus's view of imperialism. A century later, in the early twenty-first century, scholars see Rome's relationship with its provinces in a different light. With the loss of many European colonial possessions after World War II, a postcolonial approach developed that focused on reassessing the historical narratives put forth under colonial rule. Modern imperialist nations had often invoked the Roman Empire as a model for their own land grabs, stressing a view of Romanization as a force for good in spreading civilization. In the 1990s M. Millet proposed an alternative to Haverfield's concept of Romanization that emphasized the importance of material culture as a corrective to the literary tradition.[14] He advocated an approach that avoided the pro-imperialist assumptions that accompanied the traditional view of the empire. Instead, he used a model in which the process was not driven from the central power of Rome as implied by Tacitus, but instead was more spontaneous, with the elite taking a primary role in provincial governing and in adopting Roman values and the lower classes then emulating their own elite.[15] This model also came under criticism for continuing the top-down approach, and others sought to focus on the non-elites, particularly the indigenous culture made up of the less powerful. These debates sometimes led to an "either-or" mentality. For the present study, postcolonial revisionist approaches can provide a useful corrective to traditional assumptions, but one has to avoid losing perspective and, as S. Alcock put it, "throwing the baby out with the bath water" in denying any top-down model.[16] That the Roman Empire had a radical effect on the areas it conquered cannot be denied, but there are many subnarratives with native inventors as protagonists. Together these overlapping stories bring us closer to understanding the complexity of the whole.[17]

The major work in English on architecture and construction in the provinces remains J. B. Ward-Perkins's handbook, *Roman Imperial Architecture* (originally published in 1970). The basic thesis that guides the book was formed before attitudes toward the provinces had moved away from the imperialist approach that focused on the capital. For example, Ward-Perkins never mentioned many of the innovative vaulting techniques discussed in the present study, even when he was clearly aware of their existence. They simply did not fit into his narrative, which emphasized the emulation of Italian architecture in the provinces. Ward-Perkins was of a generation interested in looking for similarities between provincial architecture and that of Italy to illustrate the role that provincial builders played in Romanization, an approach that was part of the zeitgeist of

early to mid-twentieth-century Europe when many European nations still maintained colonial ties.[18] Nevertheless, in spite of the similarity of architectural forms, if one scratches the surface to see how the structures were put together, one finds that the provincial builders were not simply "borrowing," "superimposing," and "importing" existing ideas, but were actively "inventing," "innovating," and "creating" new ways of building. Recent research dealing with construction in the provinces has advanced tremendously, but it is dispersed in a wide range of publications and languages that have yet to be synthesized into any type of overview comparable to Ward-Perkins's handbook. The present study does not purport to provide such a much-needed handbook because it deals with only a very limited set of data, but it is intended as a first step toward integrating the new material into a more coherent narrative.

PROVINCIAL ADMINISTRATION AND THE BUILDING INDUSTRY

The development of the most innovative vaulting in Rome occurred largely in imperial building projects, but this was not the case in the provinces. Rarely can any of the projects discussed in this book be directly related to imperial funding or sponsorship, though local authorities may well have availed themselves of technical advice or expertise supplied by the emperor. To put the vaulting techniques discussed in the following chapters into the appropriate context, I first examine the evidence for how the projects, particularly public ones, were funded and executed.

One necessary criterion for technological innovation is the ability to finance projects, and this ability is particularly important for building technology. The vaulting techniques studied here occurred in both private and public structures. The source of funding for the former is clear, but the funding for public works, typically the largest of the monuments investigated, had greater variety. Some emperors provided funds for public buildings throughout the empire, but this was more the exception than the rule. In G. Fagan's study of the inscriptional evidence from the Latin West for benefactions of public baths, only 9.7 percent belonged to emperors and 13.3 percent to imperial officials. The vast majority of public bath construction in the West was funded by the municipal authorities (49.5 percent) or private benefactors (27.5 percent).[19] In the Greek East, studies by both P. Barresi and S. Schorndorfer reveal a similar pattern.[20] Emperors were inclined to leave the sponsorship of the most visible projects to private benefactors or municipal officials, which in turn provided these local residents a means of promoting their standing within their communities. However, there were other means for an emperor to provide aid such as donating material (e.g., marble), providing specialist expertise, and waiving taxes.

The private benefactors tended to be the male members of the elite, many of whom acted as municipal magistrates or priests, but benefactions were also made by prominent women, such as Plancia Magna at Perge and Julia Memmia at Bulla Regia.[21] Public structures could also be funded piecemeal with a combination of municipal funds and private benefactions. Examples of gifts to pay for particular parts of buildings are common, as can be seen in the "adopt a column" approach at the Temple of Zeus at Euromus and at the Temple of Aphrodite at Aphrodisias, where each column bears an inscribed dedication by its sponsor (Fig. 2).[22] Pliny the Younger describes a similar situation at Nicea (modern Iznik) where individuals funded different parts of the theater.[23] For the project that Dio Chrysostom (late first century to the early second century CE) sponsored at Prusa (modern Bursa) in Bithynia, he even claims to have measured the site and made personal trips into the mountains for some related task (for procuring

materials?).[24] Most patrons were probably not so directly involved, but the more prominent ones could have been in contact with the governor of the province or with officials in Rome itself, so that access to technical expertise outside the local environs was possible. The nature of the technology shelf varied from one region to the next, but the imperial system guaranteed a fairly wide range of possibilities for both public and private structures throughout the empire.

When the cities themselves were the major funders, income came mainly from three sources: taxation on local trade, income from public lands, and the *summa honoriaria* (payment for office) of local magistrates and priests. This last source demands some explanation because it overlaps with donations from private benefactors and provides some insight into how urbanization under the empire affected the spread of technology. A typical Roman colony was governed by a municipal council (*decuriones*); membership criteria specified a minimum age, property qualifications, and election to a magistracy. Obligations of office included the *summa honoraria*, which consisted of a minimum set amount that the elected official was expected to spend on the community from his personal wealth. Similar expectations held for elected priesthoods. Clearly those who were elected had to be able to afford the *summa honoraria*. They were often the same people who sponsored public building, and it is sometimes difficult to know from the wording of a dedicatory inscription if the benefactor was donating funds as part of his official obligation or from personal munificence.[25]

In places like Gaul and Britain where urbanism came largely with the Roman conquest, the organization of a provincial administration provided new avenues of funding for developing cities. Augustus and his successors instituted reforms, such as linking Roman citizenship to provincial magistracies and introducing newly developed priesthoods for the imperial cult, that provided ways of funneling funds via the *summae honorariae* to newly established colonies and to the *civitatis* (independent political communities) that replaced the pre-Roman *oppida* (native settlements). The system had the advantage of providing for the growth of urbanization and with it the elite class to fund it.[26] That one finds the earliest major public building projects in Gaul in the colonies (often settled by veterans), such as Narbonne, Arles, Orange, Vienne, Lyon, and Fréjus, is not surprising. As we see later, urbanization was accompanied by the building of baths, which in turn promoted innovations in vaulting technology for bath buildings. Similar funding strategies existed in the Greek East, as indicated by a letter to Trajan from Pliny the Younger when he was governor of Bithynia in the early second century BCE. He complained that the city of Claudiopolis (modern Bolu) was using the funds from the new magistracies authorized by the emperor to construct a bath building (about which he had some doubts).[27] Thus, in both the East and West, members of the municipal elite were responsible for much of the public building in one way or another.

Even though most public building projects were not imperially funded, they were often still subject to imperial oversight.[28] The third-century jurist, Aemilius Macer, noted that any structures for public assembly such as theaters, amphitheaters, and circuses must have imperial approval, regardless of who funded them. Moreover, any new building constructed with public funds also had to be approved by the emperor, as did one sponsored by a private citizen if it was intended to "outdo another citizen."[29] Such approval was presumably to help rein in competitive building and euergetism so that cities did not fall into debt. It is not clear in what period such strict oversight was instituted, but even by the time of Trajan we hear that an official was appointed to oversee the free cities of Achaea.[30] Pliny gives some evidence for his

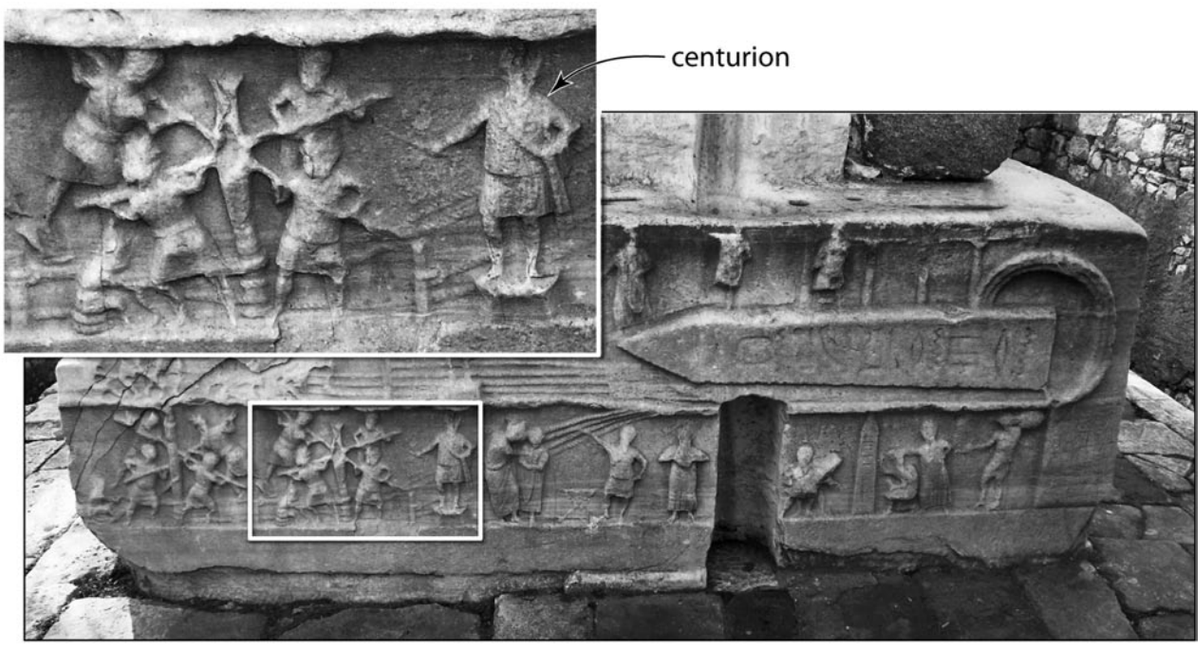
own oversight of the theater at Nicea and the bath at Claudiopolis, both mentioned earlier. Concerned about possible overspending and bad engineering, Pliny requested that Trajan send out an architect to inspect the projects, to which Trajan gave his famous rejoinder: "You cannot lack architects: every province has skilled men trained for this work. It is a mistake to think they can be sent out more quickly from Rome when they usually come to us from Greece."[31]

An example of why there was such concern for oversight can be seen in the case of Herodes Atticus who, as *corrector* of the free cities of Asia in 134/5 CE,[32] requested three million drachmas from Hadrian to provide the city of Alexandria Troas with a new aqueduct. Notably, Alexandria Troas was not one of the free cities he was overseeing, but rather was a Roman colony. When the project ran four million drachmas over budget, the officials in other cities in Asia complained to Hadrian that "it was a scandal that the tribute received from five hundred cities should be spent on the fountain of one city." In response Hadrian wrote to Herodes's father, Atticus, who immediately offered to cover the extra cost and save his son (and the family) from embarrassment.[33] In the East where competition between cities was rampant, this phenomenon may have been more problematic than in the West.

What seems clear from the inscriptional and textual evidence is that even when the imperial administration was not the source of funding for public building in the provinces, the vast imperial infrastructure of roads, harbors, safe navigational routes, and technical expertise offered advantages that expanded the technology shelf from which builders could choose. One such advantage was the availability of military personnel for construction projects requiring special knowledge of surveying, water control, complex machinery, and advanced structural design. The military served as a repository of expertise, with retired veterans, active soldiers, and specialists at hand.[34] In another of Pliny's letters to Trajan he requested an architect or *librator* (a surveyor specializing in leveling) to be sent to Nicomedia (modern Izmit) to help determine the feasibility of cutting a channel to connect Lake Sapanca to the Sea of Marmora. Trajan advised him to apply to Calpernius Macer, who was the legate in charge of three legions in Moesia Inferior in 112 CE.[35] Trajan was clearly referring Pliny to the ample supply of military experts available in a nearby province. Similarly, Ulpian, a third-century CE jurist, notes that a provincial governor should use *ministeria militaria* to evaluate and assist in construction projects.[36] Direct military intervention, however, is rarely recorded for specific civilian projects, except in cases of fortification walls and occasionally aqueduct projects.[37]

The well-known example of Nonius Datus at the aqueduct of Saldae (modern Béjaïa) in Mauretania in 152 CE demonstrates the use of both a military expert and a military labor force. Nonius Datus, who calls himself a *librator*, had been sent out from the Legio III Augusta at Lambaesis to Saldae to lay out an aqueduct tunnel, where he appointed a group of sailors and a group of Alpine troops to start digging the tunnel from opposite ends. Later when the two groups missed each other in the middle, Nonius was called back from retirement to help remedy the situation.[38] A much later example of the military engaging in a civilian project comes from the base of the Obelisk of Theodosius I (390 CE) in Istanbul, which shows a centurion directing the moving of the obelisk (Fig. 3).

Although the military may have supplied expertise at times, the primary source of labor for public projects in the provinces was through private contractors. Plutarch describes the following process: "Cities, as we know, when they give public notice of intent to let contracts for the building of temples or colossal statues, listen to the proposals of craftsmen



3. Base of the Obelisk of Theodosius I, Istanbul (390 CE). Scene of the transport of the obelisk. Detail shows soldiers (with baldrics) turning a capstan while a centurion wearing a baldric with sword and holding a centurion staff (*vitis*) directs the work.

(τεχνιτων, *techniton*) competing for the contract (ἐργολαβίας, *ergolabias*) and bringing in their estimates and models, and then choose the man who will do the same work with the least expense and better than the others and more quickly."[39] A city council would typically appoint a curator of works (Latin *curator operum*; Greek ἐπιμελητής, *epimelitis*), who would be responsible for purchasing the site and issuing the contracts, though as seen in an inscription from Miletus discussed later, an architect could also issue contracts.[40]

Under Roman law, building contracts were typically a type called *locatio conductio operis* (lease and hire). The patron (*locator*) let out a job to be completed by the builder (*conductor*). The contract included a final inspection (*probatio*) and an agreed-on price (*merces*). The builder took on responsibility for the site until the final inspection of the work,[41] which released him of responsibility. Similar types of contracts governing lease and hire existed under Greek law, called μίσθωσις (*misthosis*), which included building contracts. Whether local law or Roman law prevailed in the provinces was not strictly defined. Generally the "personality principle" was used whereby disputes between two non-Roman citizens would be settled using local law and those between two Roman citizens using Roman law. For disputes between those of mixed citizenship some ambiguity existed, and other factors were considered, such as the amount of money involved and the status of the disputing parties, with the governor of the province stepping in when large sums and important people were involved.[42] Once Roman citizenship was extended throughout the empire under Caracalla, these distinctions theoretically would be mute. In contracts of both *locatio conductio operis* and *misthosis*, detailed specifications could accompany the agreement, along with deadlines for completion and