Vertical connectors between successive drums in ancient columns: literature and in-situ investigation

V. Palieraki[1], E. Tavouktsi[2], E. Karakike[3] and C. Arvanitis[4]

[1]*Hellenic Ministry of Culture and Sport, Directorate for the Restoration of Ancient Monuments, Athens, Greece; National Technical University of Athens, Faculty of Civil Engineering, Laboratory of Reinforced Concrete, Athens, Greece; vasopal@central.ntua.gr*

[2]*National Technical University of Athens, Faculty of Civil Engineering, Laboratory of Reinforced Concrete, Athens, Greece; e.tavouktsi@gmail.com*

[3]*Hellenic Ministry of Culture and Sport, Directorate of Research and Technical Support for Restoration Projects, Athens, Greece; National Technical University of Athens, Faculty of Civil Engineering, Laboratory of Reinforced Concrete, Athens, Greece; ekarakike@yahoo.gr*

[4]*National Technical University of Athens, Faculty of Civil Engineering, Laboratory of Reinforced Concrete, Athens, Greece; arvanitis.kwstas@yahoo.com*

ABSTRACT

Vertical connectors (in greek called "gomfoi"), were placed between successive drums in ancient columns. Even though it was a widespread construction feature of ancient architecture, it is insufficiently documented. The present article collates existing literature and new field observations in order to describe their geometry, materials, positioning and associated pathology in a broad range of monuments from Classical, Hellenistic and Roman times. The study covers sites in Greece and in eastern Mediterranean area and aims to clarify the extent to which this construction technique was adopted, the variations it exhibits across regions and periods, and the typical damage patterns observed today. By bringing together scattered references and systematic on-site measurements, the paper seeks to provide an overview that can serve as a reference for future architectural and structural studies of ancient multi-drum columns.

Keywords: ancient monuments; columns; vertical shear connectors ("gomfoi"); ground penetrating radar; in situ investigations

INTRODUCTION

Ancient stone monuments of Classical, Hellenistic and Roman antiquity are constructed with dry joints, that is, with stone placed without mortar. As architectural practice evolved and as monuments suffered damage, particularly under earthquake action or due to long-term environmental effects, metal and timber vertical and horizontal connectors were increasingly introduced to enhance the connectivity between blocks and to limit relative displacements (Adam, 2005). Horizontal connectors (clamps) joining adjacent blocks in walls, architraves and other horizontal members have received considerable attention in the literature (Orlandos, 1994; Bouras & Korres, 1983; Mueller-Wiener,1995), both from archaeological and structural points of view, whereas vertical connectors between successive drums in columns have been discussed far less, despite their potential importance for the overall behaviour of multi-drum columnar systems.

Vertical connectors were metal or timber elements placed in grooves cut into the surfaces between drums (Figure 1). The were usually sealed with lead, and intended to tie the courses together (Bouras & Korres, 1983). Their presence has often been noted incidentally in excavation reports or architectural descriptions, and grooves for their placement are visible in many drums stored in archaeological sites. However, systematic information about their dimensions, number, exact positions and relation to column geometry has remained sparse and dispersed across different publications. This lack of synthesis

makes it difficult to understand how widespread the use of such connectors was. Furthermore, it is not sufficiently studied which design patterns were preferred in different regions or periods and how these choices relate to the observed condition of the monuments today.
This present paper aims to organise available information on vertical connectors between successive drums, combining it with selected field observations at selected sites. The paper focuses on documentation and records how vertical connectors are shaped and where they are positioned in relation to drum geometry.

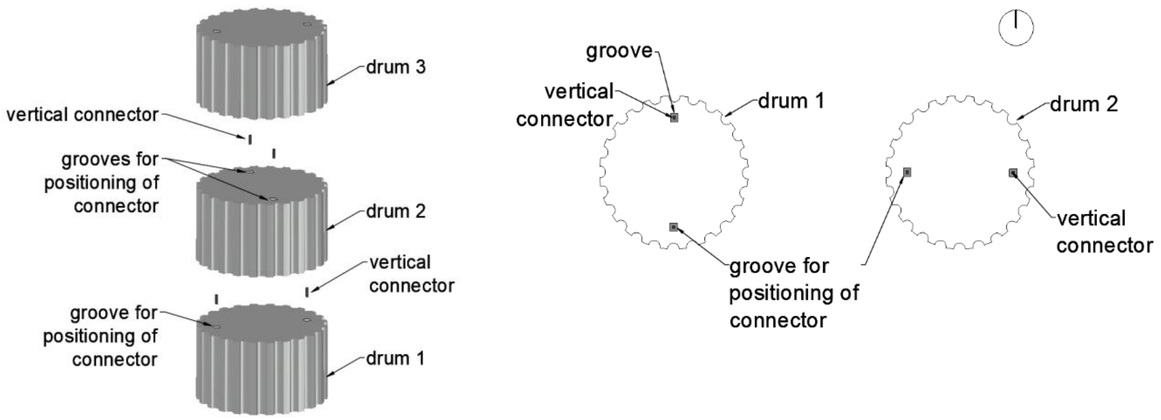

Figure 1. *The arrangement of vertical connectors between consecutive drums, in one of the columns (B18), in the Temple of Olympian Zeus, Athens.*

METHODS AND SOURCES

The research is based on a combination of literature study, in-situ observation and, in specific cases, non-destructive testing. Published material including archaeological reports from excavations, architectural studies devoted to individual monuments, journal articles dealing with construction details and structural behaviour were used. Furthermore, online resources that present photographs or drawings of vertical connectors between column drums were taken into consideration. One of the main tools for the internet investigation, for monuments in Greece, has been the site of the Greek Ministry of Culture, http://odysseus.culture.gr/. For each monument identified in the literature, information was collected regarding its location, approximate date, type of building, architectural order, the reported presence and number of connectors, their arrangement in plan, and any available measurements of grooves or vertical connectors (“gomfoi”).
On-site investigations were organised at several archaeological sites in Greece. Particularly, these included, among others, the Acropolis of Athens, the archaeological sites of Eleusis, Delos, Epidavros, Olympia and Ancient Messene, as well as areas around the Stoa of Attalos in the Athenian Agora. During these visits, visible grooves were systematically examined and measured with simple tools, typically recording their dimensions (length, width, depth where possible), their distances from the drum edge and their positions in relation to other features such as flutes. Photographs and sketches were produced to document the arrangement of connectors within each joint. Particular attention was paid to signs of cracking, local spalling and other damage that could be associated with the presence of connectors.
In a small number of cases, where grooves were not visible or where there was a need to confirm the presence of metal elements within columns that remain standing, ground penetrating radar (GPR) was implemented. GPR has been applied extensively in the last three decades for the investigation of existing structures in a non-destructive manner. GPR is based on the transmission of electromagnetic waves through a medium (Utsi, 2017). The system consists of a central (control) unit, which is connected to an antenna. Depending on the frequency of the pulse transmitted by the antenna, different maximum ranges of penetration and different grades of accuracy are achieved.
GPR, which is commonly used for the investigation of historic structures, allows the detection of changes in material and is particularly sensitive to metallic inclusions within stone. At the Temple of Olympian Zeus in Athens, for example, scanning using the ground radar was performed on columns and their sections to document the existence of vertical connectors in areas where traces of lead were detected, as well as in areas where there is no visible evidence. It is noted that all flutes of the columns were systematically scanned, in order to fully document and detect the eventual connectors.

OVERVIEW OF MONUMENTS WITH VERTICAL CONNECTORS

The compiled documentation confirms that vertical connectors between successive drums are present in a large number of monuments across the eastern Mediterranean (Greece, Turkey, Lebanon, Syria and Italy). Construction dates range from the late Classical period to the Roman Imperial era, roughly between the fourth century B.C. and the second century A.D.

In Greece, documented examples include the Tall Monument of Ptolemy in Olympia, where columns are described as being characterised by "firm dowelling" used in an unusual pattern (Partida, 2016); the Temple of Athena on Kea (Simantoni- Bournia et al, 2013); elements of the theatre in Sparta (Vasilogamvrou & Zambas, 2011); several buildings in the archaeological site of Samothrace; the Temple of the Twelve Gods and the Stoa of Philip V in Delos; the Temple of Olympian Zeus in Athens (Korres, 1999; Tavouktsi et al, 2025); various column fragments in the archaeological site of Eleusis; drums associated with the Stoa of Attalos in the Athenian Agora; two choregic columns on the south flank of the Acropolis (Zambas et al, 2011); and columns in the gymnasium of Ancient Messene (Themelis, 2009). In many of these sites, the presence of connectors was inferred from photographs or drawings showing grooves in the drums, and was subsequently confirmed by in-situ inspection.

In Asia Minor, vertical connectors have been reported or identified in the Temple of Athena at Priene (Priene, wikipedia); the Temple of Zeus Olbios in Diocaesarea (Archaeological Atlas of Antiquity); the agora and nymphaeum at Sagalassos (Sagalassos, arts KULeuven); the sanctuary of Athena at Pergamon (Pergamon, wikipedia); the porticoes at Laodikeia (Şimşek, 2013); the gymnasium and "Marble Stoa" at Hierapolis (Ismaeli, 2013); the Temple of Artemis at Sardis (Fikret, 2020); the Temple of Apollo at Claros and the columnar structures of Magnesia on the Maeander (Arisoy, 2011; Aylward, 2012). These monuments represent a variety of orders and scales, from moderate peripteral temples to very tall columns with many drums, and provide a rich set of examples for studying the variation in connector arrangements.

Further east, evidence of vertical connectors has been noted in the great sanctuary of Baalbek (followinghadrianphotography.com), where some fallen columns show three or four grooves near the edges of drums; in the Great Temple at Niha, where vertical connectors are associated with the adyton (Paturel, 2019); and in the monumental colonnades at Palmyra, where photographs reveal multiple grooves and channels for lead pouring. In Italy, relevant examples include the Basilica Julia in Rome (historyhit.com) and the theatre at Privernum, where drums with two or three grooves for metal rods have been documented.

Altogether, the range of sites indicates that the use of vertical connectors was not a local peculiarity but a widespread technique employed in different architectural traditions that shared similar construction practices.

CHARACTERISTICS OF VERTICAL CONNECTORS

The research resulted in common features that can be discerned in the geometry and positioning of vertical connectors. In many monuments, two connectors are used between successive drums, placed off-centre near the perimeter of the drum and roughly aligned along a diameter. In other cases, three or four connectors are present and their positions may follow specific patterns, such as two pairs arranged symmetrically or an irregular distribution that reflects particular design choices. The grooves in which the connectors are placed are typically rectangular or square in plan, with side dimensions of a few centimeters, and with depths sufficient to house metal elements of significant length; in some examples, their depth and the presence of pour channels suggest connectors extending well into both adjoining drums.

Measurements from sites such as the Temple of Artemis at Sardis (Fikret, 2020) and the gymnasium at Hierapolis (Ismaeli, 2013) indicate groove dimensions of about 5 by 5 or 5 by 6 cm and distances in the order of 30 to 40 cm from the drum edge, although the exact figures vary according to column diameter and design. In some monuments, the vertical connectors are always placed along the same direction from joint to joint, while in others their orientation changes, as is the case in the two choregic columns on the Athenian Acropolis.

The materials of the connectors appear to follow broader chronological and technological trends. Literary sources and excavation reports refer to wooden vertical connectors in some early examples, to bronze and iron connectors in Hellenistic and Roman-period constructions. In numerous cases, the connectors themselves have been removed or severely corroded, and only the empty sockets or traces of lead sealing remain visible on the stone surfaces. Where metal is still present, corrosion products and rust staining are often clearly associated with cracking and spalling of the surrounding marble or limestone, indicating that expansion of the corroded metal has exerted significant pressure on the stone. At the

Temple of Olympian Zeus (Korres, 1999; Tavouktsi et al., 2025) and at the choregic columns (Zambas et al., 2011), for instance, extensive cracking radiating from the regions of the grooves is commonly observed and has been attributed primarily to long-term rusting of iron connectors.
Generally, a rough evolution can be discerned in the use and detailing of vertical connectors. In many Classical-period structures, polos–empolion systems were placed between drums, mainly in the centre of the drum (Orlandos, 1994). Research regarding the polos-empolion system has shown that it is mainly used for the easier positioning of the consecutive drums (Bouras & Korres, 1983) and it is not further investigated in the current paper. From the Hellenistic period onwards, monuments increasingly show two or more connectors placed away from the centre of the drums, and these become common in the Roman Imperial era, where iron dowels and elaborate lead sealing details are frequently reported. This progression suggests that the technique became more widely adopted and perhaps more systematically designed over time, although local variations and exceptions remain significant.

SELECTED EXAMPLES- IN SITU INVESTIGATIONS

The Temple of Olympian Zeus in Athens, often referred to as the Olympieion (Figure 2), offers a particularly revealing example because of its long and complex building history and the scale of its columns. Early phases of construction appear to have no traces of lead and therefore to have relied mainly on centrally positioned empolia and on horizontal clamps to connect blocks, whereas later, during the Roman period, off-centre vertical connectors were introduced between the drums of the colossal columns (Korres, 1999). Exposed drums lying on the ground display elongated rectangular grooves near the drum edges (Figure 3), often in pairs (Figure 1), together with channels leading from the grooves to the outer surface for pouring lead around iron connectors. In many cases, the stone around these grooves shows pronounced cracking and chipping, as well as rust stains, indicating that the connectors have corroded and expanded over time or that attempts have been made to remove them. The application of GPR on selected standing columns at the site has confirmed the presence of internal metal elements at depths corresponding to the visible grooves and revealed localised reflections consistent with cracks around the connectors.
The southwest corner of the Temple of Olympian Zeus preserves the largest number of surviving columns, with thirteen still standing. Scaffolding installed around the nine corner columns provided access for detailed inspection of the column drums. Among the nine columns examined, only one column (with the name A3, Figure 2) exhibits traces of lead on the outer surface of its drums, suggesting the presence of a connector (Figure 4). No visible evidence of connectors was identified on the remaining eight columns. Ground Penetrating Radar (GPR) scanning was undertaken to investigate the presence of vertical connectors within the columns. The survey targeted both areas where traces of lead were visible and columns lacking external indications of connectors. GPR scanning, using a portable GPR system manufactured by GSSI, equipped with an antenna mounted on a wheeled platform, was conducted to (1) verify the presence of visually identified connectors and (2) investigate the internal structure of columns without visible indications of vertical connectors. The scans were performed along the vertical axis of all flutes, as already mentioned, moving from top to bottom. In total, 250 scans were conducted and subsequently processed. To calibrate the method, GPR measurements were performed on columns, in areas adjacent to visible lead traces. The results produced the expected qualitative response, confirming the presence of a vertical metallic connector within the column drums.

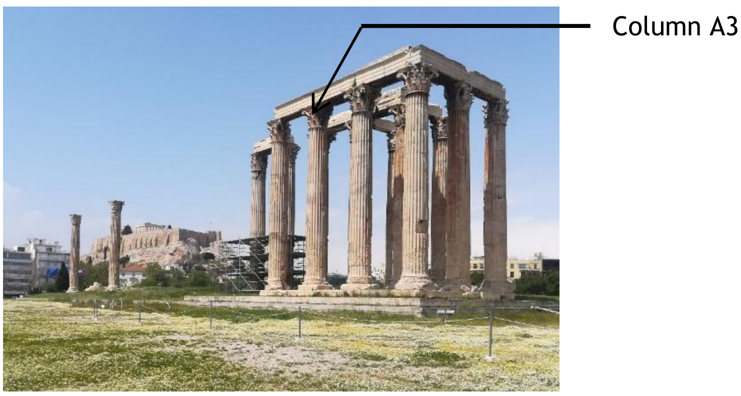

Figure 2. *The Temple of Olympian Zeus, Athens.*

The interpretation of the radar data relies on contrasts in dielectric constants between adjacent materials. Metallic elements typically generate reflections of significantly higher intensity than non-metallic materials. When the antenna moves perpendicular to an element, intersection produces a hyperbolic signature. Consequently, vertical metallic connectors are expected to appear as high-intensity hyperbolic reflections in the radargrams.
The GPR results confirm the visual observations, in case of columns with external signs of connectors. Processed radargrams reveal distinct hyperbolic reflections corresponding to vertical connectors at relatively shallow depths and within specific flutes, primarily along the north–south and east–west orientations. Additionally, also scanning of columns without lead traces resulted in the conclusion that connectors were used between successive drums. It is noted that the scanning positions are very important: Scanning of flutes away from the connectors could lead to the incorrect conclusion of the non-existence of connectors, while scanning of flutes where connectors are positioned leads to their systematic detection in all the columns that were investigated.

Figure 3. *Measuring the main dimensions of interest, in the Temple of Olympian Zeus, Athens.*

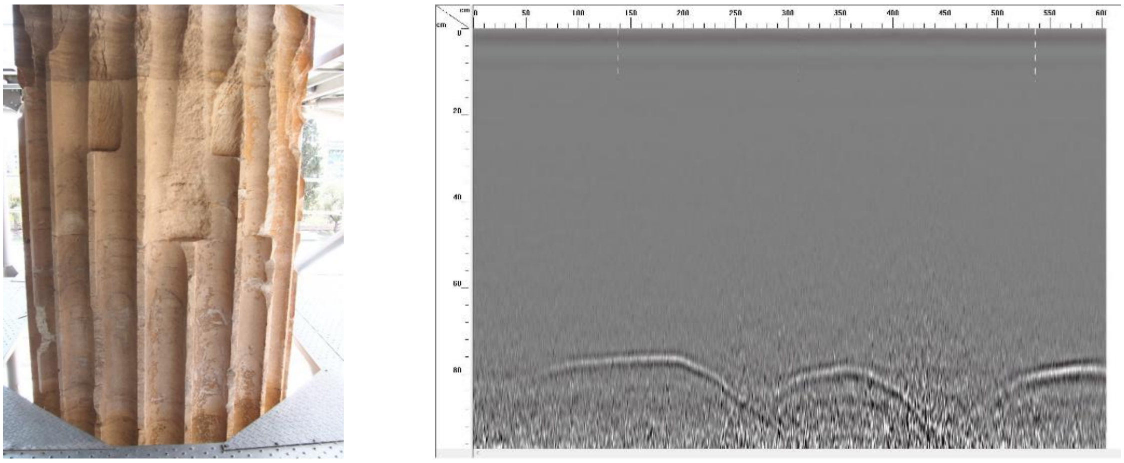

Figure 4. *Column A3. Flut "α". No traces of lead between the drums (left), Scanning with georadar, the result of scanning. No hyperbolic reflections at a small depth can be observed, while deeper the reflections in-depth, of the polos-empolio system, are visible (right).*

Another important monument in which vertical connectors between successive drums are located is the gumnasium in Ancient Messene. In the gymnasium, columns consisting of several drums exhibit between two and four connectors between courses. Measured groove dimensions are of the order of 4cm on a side, and positions are typically near the perimeter of the drums. The literature and field observations suggest a combination of bronze and iron connectors, with bronze more frequent in lower drums and iron in upper ones, although detailed confirmation of this distribution would require selective opening of joints (Figure 5). The observable pathology is relatively moderate and includes some cracking in upper drums, mild deformation of joints and local degradation of the stone, which may be attributed to a combination of corrosion, environmental action and human intervention, rather than to a single cause. The gymnasium thus provides an example of a many-drum colonnade in which vertical connectors were evidently used as a regular construction element.

Figure 5. *The Gymnasium, in the archeological site of Ancient Messene: The construction of the corner and the form of the epistyles (left); Drum, the iron connector can be seen (middle); Drum with grooves and channel for the lead pouring (right).*

At Epidavros, the sanctuary of Asclepius comprises several buildings with columnar elements in which vertical connectors have been documented (Figure 6). The Ceremonial Restaurant, the Temple of Artemis, the Avaton and the Stoa Kotyos all show evidence of connector's use between drums, with two connectors in most cases and four in at least one building. Many of the drums lie on the ground and can be examined closely, revealing grooves in the bedding surfaces and, occasionally, remnants of metal or lead within them. The generally good state of preservation of these columns, combined with the clearly visible provision for connectors, indicates that this technique was considered appropriate and effective in this context and was applied consistently across different structures within the sanctuary.

Figure 6. *Epidavros, photo of one of the drums (left) and one of the capitals of the Avaton (right).*

In the archaeological site of Eleusis, various column fragments display grooves that may correspond either to vertical connectors or to lifting devices such as lewis holes, and distinguishing between these functions requires careful consideration of shape and location. Some grooves are located near the centre of the drum and have forms typical of lifting devices, whereas others are placed nearer the perimeter and are more likely to have housed vertical connectors. The column lying at the entrance to the site, for instance, shows grooves whose form and position suggest that they were used for fastening rather than lifting, although certainty is not always possible.

DISCUSSION

The research demonstrates that connecting successive drums with vertical connectors was not an exceptional or localised practice but rather a widespread technique employed in a variety of architectural settings and over several centuries. The use of vertical connectors was a common construction practice in a wide range of structures dating to the Hellenistic and Roman periods, including temples as well as other public buildings such as gymnasia. The number, position and dimensions of connectors vary between monuments, but certain recurring patterns can be recognised, such as the frequent use of two off-centre connectors in smaller columns and more numerous connectors in larger or particularly important structures. The choice of material appears to follow broader chronological and technological trends, with timber and bronze more common in earlier periods, and iron becoming dominant in the Roman and Hellenistic era, with corresponding changes in corrosion behaviour and long-term effects on the stone. The observed pathology, including cracking spalling of the stone substrate, illustrates the long-term consequences of metal corrosion, the function of the connectors and of interventions aimed at removing valuable metal elements. The main monuments in which connectors were located, are described in Table 1.

Two principal categories of columns incorporating vertical connectors can be distinguished: The first category includes relatively small columns, with heights ranging from approximately 4.0 to 5.0 m. These columns typically consist of three to five drums, including the capital, and are characterized by a relatively high slenderness ratio exceeding 1.0. The second category comprises monumental columns. These elements exceed 10.0 m in height and are generally composed of ten to eighteen drums. Their lower diameters typically range between 1.5 m and 2.0 m, while their slenderness ratios are significantly lower, usually around 0.50. The reduced slenderness ratio observed in the second category is likely related to practical construction constraints. In particular, obtaining stone blocks of sufficient quality to produce drums with diameters approaching 2.0 m and comparable heights would have been challenging. Moreover, the transportation of such large and heavy elements to the construction site would have posed considerable logistical difficulties.

The combination of literature review, direct observation and GPR investigation has proved effective in uncovering and documenting these connectors and their present condition. For monuments where grooves are not visibly accessible or where the state of standing columns cannot be assessed by simple inspection, non-destructive techniques allow the detection of internal metal elements and associated defects, providing an essential complement to surface examination. The data gathered form a basis for more detailed future studies of the structural role of vertical connectors and has supported experimental and analytical work on the behaviour of multi-drum columns under various actions, as already performed within the IAMON research framework. They also offer a systematic point of reference for architects, conservators and engineers who are planning interventions in monuments where such connectors are known or suspected to exist.

Table 1. *The main information regarding monuments with connectors between successive drums.*

Monument/ Site	Date	Type of Monument	Nr of connectors/ Column Height/ Diameter/ Nr of drums
Tall Monument of Ptolemy/ Olympia, Greece	Early 3rd century B.C.	Two tall columns	2 or 3/ 8.50m/ 0.90m/ 8+capital
Temple of Athens/ Kea, Greece	500 B.C.	Doric Temple, attributed to Athena	2/ 4.55m/ ~0.70m/ 5+ capital
The archeological site in Samothrace/ Samothrace, Greece	Mid-third century B.C.	Stoa	2/ n.a.
	Late Hellenistic period, 2nd century B.C. or later	Northern two buildings and southern-most building	2/ n.a.
	323-317 B.C.	Fieldstone building, and Dedication of Philip III and Alexander IV	2/ n.a.
	First half of the 3rd century B.C.	Neorion (shipyard)	2/ n.a.
Temple of Athena, in Priene/ Priene, Turkey	350/340 B.C., completed in the mid-2nd century B.C.	Ionic peripteros of 6 × 11 columns	2/ n.a.
The archeological site in Sagalassos/ Sagalassos, Turkey	160–180 A.C.	Mid-Antonine nymphaeum and two honorific columns	2/ n.a.
The archeological site in Pergamon/ Bergama (Pergamon), Turkey	4th century B.C.	Sanctuary of Athena, Doric peripteros temple, 6×10 columns	2/ n.a.
Laodikeia antique city/ Phrygia, Turkey	3rd century B.C.	Columns of the City Portico	2/ n.a.

Heliopolis (City of the Sun)/ Baalbek, Lebanon	Roman period	Well-preserved sanctuary of Jupiter, Venus and Mercury	2, 3 or 4/ n.a.
Great Temple at Niha/ Niha, Lebanon	Beginning of the 2nd century A.C. mid- 3rd century A.C.	The adyton of the Great Temple	2/ n.a.
Primary Temple of Bel/ Palmyra, Syria	1st century A.C.	The propylaeum, in the primary temple, dedicated to Bel	4/ n.a.
Basilika Iulia/ Rome, Italy	Initially founded in 54 B.C., completed in 12 B.C.	Civil courthouse in the Roman Forum	3/ n.a.
Privernum/ Latina, Italy	End of the 1st-beginning of the 2nd century A.D.	Scaenae frons of the theater of Privernum	2 or 3/ n.a.
Gymnasium of Hierapolis/ Hierapolis of Phrygia, Turkey	1st century A.D	Colonnade of Gymnasium	1 or 2/ ~4.40m/ ~0.50-0.65m/ 3+ capital
Temple of Artemis in Sardis/ Sardis, Turkey	Roman period	east peristyle colonnade of the Artemis's temple	2/ 17.87m/ ~1.80m/ 19-20+capital
Temple of Apollo in Claros / Claros, Turkey	3rd century B.C.	Temple of Apollo	2/ 9-11m/ n.a./ 9-11+ capital
Neorion (shipyard)/ Mesolonghi, Greece	4th century B.C.	Neorion (shipyard)	2/ n.a.
Temple of Athena Alea/ Tegea, Greece	4th century B.C.	Temple of Athena Alea	2/ ~17.50m/ ~1.30m/ 10-12+capital
The archeological site of Epidavros/ Epidavros, Greece	end o4th century B.C.	Temple of Artemis	2/ ~4.00m/ ~0.60m/ 5-6+capital
	end o4th century B.C.	Avaton	2/ ~4.00m/ ~0.50m/ 3-5+capital
	2nd century A.D.	Stoa Kotyos	2/ n.a./ ~0.45m/ n.a.
The archeological site in Olympia/ Olympia, Greece	2nd century B.C	The portico of the Gymnasium	2/ n.a./ n.a./ 2 + capital
	3rd century B.C.	Palestra	4/ n.a.
	350 B.C.	Echo colonnade	2/ n.a.
Two choregic columns, Acropolis South flank/ Athens, Greece	Early Hellinistic reriod	Two tall columns	2/8.79-10.27m/ 0.93-1.28m/ 5-6+capital
Gymnasium of Ancient Messene/ Ancient Messene, Greece	Hellinistic reriod	Gymnasium	2/ 3.82m/ ~0.55m/ 1-3+ capital
The archeological site of Delos/ Delos, Greece	320 B.C. - 280 B.C.	Temple of the Twelve Gods	1 or 2/ 3.55m/ ~0.55m/ 3+capital
	end of the 3rd century B.C.	Colonnade of stoa of Philip V	1 or 2/ n.a.
Temple of Olympian Zeus/ Athens, Greece	1st century B.C. - 2nd century A.D.	Temple of Olympian Zeus	2/ ~18.0m/ 1.73-2.03m/ 15+capital

CONCLUSIONS

Vertical connectors between successive drums in ancient columns are widely used in monuments of Hellenistic and Roman date across the eastern Mediterranean and constitute an integral part of historical construction practice. Their systematic documentation, through literature study, in-situ investigation and non-destructive testing, reveals common patterns of geometry and positioning and a range of damage phenomena associated mainly with corrosion and stone deterioration. The findings show that connectors were not confined to a small number of exceptional monuments but were applied in many temples, stoas, theatres and colonnades, often with consistent patterns within a given site or building complex. The compiled information enriches the understanding of ancient column construction and offers a structured reference framework for future research on the behaviour and conservation of multi-drum columnar structures.

ACKNOWLEDGEMENTS

The research project was supported by the Hellenic Foundation for Research and Innovation (H.F.R.I.) under the “3rd Call for H.F.R.I. Research Projects to support Post-Doctoral Researchers” (Project Number: 7340).

REFERENCES

Adam, J.-P. (2005). Translated by Matthews, A. ROMAN BUILDING Materials and Techniques; Taylor & Francis e-Library, London, UK, 360 p.; ISBN 0-203-98436-6.

Archaeological Atlas of Antiquity. Available online: https://vici.org/vici/17371/ (accessed on 5 November 2024).

Aylward, W. (2012). Lewis Holes at Claros. In Proceedings of Le sanctuaire de Claros et son oracle. Actes du colloque international de Lyon, Lyon, France, 13-14 January 2012: 63-74.

Arisoy, B., Nuhoglu, A., Ercan, E. (2011). Seismic response of multi-drum classical columns of Apollo Temple at Claros. Scientific Research and Essays, 2011, 6(2): 283-292.

Bouras, C., Korres, M. (1983). Study for the restoration of the Parthenon; Committee for the Conservation of the Acropolis Monuments, Athens, Greece (in Greek, summary in English).

Fikret, Y. (2020). Report 7: The Temple of Artemis at Sardis; Harvard University Press, Massachussets, USA.

History hit. https://www.historyhit.com/locations/basilica-julia/(accessed on 5 November 2024).

Ismaeli, T. (2013). Ancient architectural restoration in Asia minor: Typology, techniques and meanings discussed with reference to examples of large-scale public buildings in Hierapolis of Phrygia, a seismic city in western Turkey. Istanbuler Mitteilungen, 63, 267-324.

Korres, M. (1999). Olympieion. Athemion, 1999, 5, 27-29.

Mueller-Wiener, W. (1995) Translated in Greek, Griechisches Bauwesen in der Antike; University Studio Press, Thessaloniki, Greece.

Orlandos, A. (1994). The building materials and architectural techniques of the ancient Greeks, as evidenced by the authors, the inscriptions and the monuments, 2nd ed.; Library of the Archaeological Society in Athens, 37, Athens, Greece (in Greek.

Palieraki, V., Vintzileou, E., Miltiadou-Fézans, A., Delinikolas, N. (2008). The use of radar techniques and boroscopy in investigating old masonry: the case of Dafni Monastery; Int. J. of Arch. Heritage, 2(2), 155-186.

Palieraki V., Oikonomopoulou E., Nikolopoulou V., Vintzileou E., Giannelos C. (2023). The Historical Bridge of Konitsa-Epirus, Greece: Documentation of the Structural System; Int. J. of Arch. Heritage, 17(9), 1446–1463.

Partida, E.C. (2016) Post-earthquake architecture at Olympia: The impact of natural phenomena upon the builders’ attitude in the 4th century B.C. ΦΙΛΕΛΛΗΝ - Essays presented to Stephen G. Miller.

Paturel, S.E. (2019). Baalbek-Heliopolis, the Bekaa, and Berytus from 100BCE to 400CE A Landscape Transformed (Mnemosyne supplements -426); Brill, Leiden- Boston, USA. p. 343, ISBN 9789004400580.

Pergamon, wikipedia. Available online: https://en.wikipedia.org/wiki/Pergamon (accessed on 5 November 2024).

Priene, wikipedia. Available online: https://de.wikipedia.org/wiki/Athenatempel_von_Priene (accessed on 5 November 2024).

Sagalassos Archaeological Research Project - Faculteit Letteren. Available online: https://www.arts.kuleuven.be/sagalassos (accessed on 5 November 2024).

Şimşek, C. Laodikeia (Laodicea ad Lycum). Laodikeia Works 2; Ege Yayınları, Istanbul, Turkey, 2013; 106 p.

Simantoni- Bournia, E.; Panagou, T.; Mavrocordatou, D. Karthea and the Tower of Sainte Marina, in Kea. A twelve year effort (2002-2013). In Proceedings of The Archeological Project in the Aegean Islands, International Conference, Rhodes, Greece, 27 November- 1st December 2013.

Tavouktsi, E., Arvanitis, K., Palieraki, V., Vintzileou, E. (2025). Seismic response of a free-standing column and the role of connectors: The case of column B18 of the Temple of Olympian Zeus in Athens. In: Proceedings of the 6th Panhellenic Conference on Earthquake Engineering and Technical Seismology (6PSAMTS), Athens, Greece, 30 October – 1 November 2025 (in Greek).

Themelis, P. (2009). Das Stadion und das Gymnasion von Messene. Nikephoros 2009, 22, 59-74.

Utsi, E. (2017). Ground Penetrating Radar: Theory and Practice; Butterworth-Heinemann, Elsevier.

Vasilogamvrou, A., Zambas, C. (2011) Ancient Theater of Sparta: Sponsorship File. Athens, Ministry of Culture and Tourism, 5th Ephorate of Prehistoric and Classical Antiquities, Diazoma (in Greek).

Zambas, C., Ambraseys, N., Boletis, C., Zamba, I. (2011). The two choregic columns on the S flank of the Acropolis as witnesses of the seismic history of the centre of Athens. In Research studies 2011, Latsis Foundation, Athens, Greece (in Greek).