The Role of Roman Building Techniques in the Sustainability of the Road System in the Roman Empire

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Abstract

The roads of ancient Romans testify the civil engineering skills in service of the Empire. Building the road networks witnessed many types of progress and development appeared in the several and thickness of the layers of the roads, the compacted concrete, the drainage system, intentional ruts, the width of the roads and the courier system. But the most intensive period of progress was during the reign of the emperors Augustus (27 BC.-14 AD.), Trajan (98-117 AD.) and Hadrian (117-138 AD.), whose periods witnessed a lot of architectural Transformation of the road networks.

Roman road networks are well-known for their durability and engineering proficiency. Even though being approximately two thousand years old, many of these ancient roadways remains exist in the present day e.g., the well-known via Appian in Italy and via Hadrian in Egypt. In contrast, modern roadways often frequently require repairs and maintenance. So, what were the main reasons for these massive and costly projects? What makes Roman roads so long-lasting? These are the major questions that this research aims to investigate.

Furthermore, to raise awareness of the significance of Roman road networks, as well as to encourage stakeholders to maintain and improve these routes because contemporary urbanization, or just forgetfulness, threatens the sustainability of this significant historical heritage.

Keywords: Roman Egypt, Road Networks, Construction materials, Construction Techniques, Sustainability.

Introduction

The Romans created exceptional road networks that needed methodical planning, creative design and outstanding building and preservation abilities. The Roman road networks were congested with soldiers, merchants, and passengers. Despite their regular use, they remained intact thanks to their strong structure.

According to Vitruvius in his book De Architectura I, V.2, 1st century AD, he indicated that an extensive surveying was done around the area previously a new road was constructed; these highly important surveying assisted in identifying the best possible road to eliminate the most obstacles and create direct path as possible.

The Romans adopted paving techniques from the Phoenicians, stonework from the Greeks, and skills of surveying from the ancient Egyptians. In general, two main stages of Roman road building can be recognized: road surveying, design and the tangible building. The former stage was consisting of numerous steps, containing processes of excavation, drainage, filling and paving[1].

I. Who were the Builders of the Roman Roads?

In the Greco-Roman era, armies were tasked with more than just combat; and one of their key responsibilities was the planning and construction of roads[2]. Consequently, military engineers were represented an essential and vital part of the Roman army, and their expertise in building roads, fortifications, bridges, and aqueducts was invaluable and their skills played a crucial role in facilitating troop movements and enhancing communication and trade across the empire, thereby strengthening and stabilizing it(Figure 1).[3]

II. The Main Purposes of Road Construction

The Roman roads served many purposes, including trade, travel, and migration. However, the primary purpose was military transportation. The roads were sturdy, wide and paved to transport soldiers, horses, and military equipment to and from different parts of the Roman Empire as quickly and efficiently as possible[4].

II.I. Military Purpose

These roads were renowned for their advanced engineering design and often extended over long distances in perfectly straight lines, which became a distinctive feature of Roman roads. This design greatly facilitated the movement of troops, trade, and communication across the Roman Empire, thus enhancing its power and stability(Figure 1).

In some cases, roads traversing hilly terrain were designed with gentle curves to navigate challenging landscapes and to aid in rainwater drainage, demonstrating the precision and ingenuity of Roman engineers. To ensure their durability over time, these roads were

[1] Joseph Berechman, (2003), Transportation-economic aspects of Roman highway development: The case of Via Appia, Transportation Research Part A 37 (2003) PP. 453–478. P.461.

[2] Lewis, N., Reinhold, M. (Eds.), (1990), Roman Civilization, Vol. II, Columbia University Press, NewYork, P. 127.

[3] Cornelis van Tilburg, (2007), Traffic and Congestion in the Roman Empire, Routledge: London & NewYork, P.10.

[4] Lewis, N., Reinhold, M. (Eds.), (1990), P. 127.

regularly maintained, reflecting the Romans' commitment to building a robust and enduring infrastructure and their awareness of the importance of preserving it. These roads were not merely transportation routes but served as vital arteries that supported the expansion and influence of the Roman Empire[5].

The Roman civilization was considered one of the greatest and most powerful ancient civilizations, largely due to its advanced military strategies and reliance on legions for expansion and conquest. Utilizing these legions necessitated significant improvements in infrastructure to support their transportation, as Roman forces needed to traverse vast distances to reach combat zones and secure new territories.[6]

The challenges of moving troops, military equipment, horses, and other essential supplies over rugged dirt roads required considerable effort. As the empire expanded and acquired more land, the Romans recognized the need for a sophisticated network of roads to facilitate military and administrative functions. Consequently, they constructed extensive road systems across various provinces to enhance troop mobility, expedite supply lines, and reinforce control over newly conquered areas. These roads not only supported military operations but were also crucial for effective provincial management and improved communication throughout the empire[7].

Furthermore, these roads played an additional role in reducing travel time and fatigue, allowing soldiers to complete their tasks more swiftly and with less effort. Thanks to the enhancements in the Roman Empire's road network, legions were able to move with remarkable efficiency, covering distances of up to about 20 miles per day[8].

This efficiency was crucial for responding effectively to internal uprisings and external threats. Additionally, a well-organized road network enabled the rapid deployment of reinforcements and supplies, including troops and weapons, even to remote and isolated areas during emergencies. This greatly contributed to the ease of rapid military mobilization and immediate support across the empire, enhancing its ability to control and manage threats effectively.

II.II. Trade Activity

With the rapid population growth in the ancient world, trade emerged as a crucial component for economic stability and prosperity. The expanding population created a significant demand for goods and resources, which drove the necessity for effective trade

[5] Fields, N., & Anderson, D. (2008), The Roman army (88-31 BC.), Oxford: Osprey, P. 85.
[6] Palombi. F. (1995). Via Appia, the ancient Roman road. Rome, P. 163.
[7] Charles R. Gildart, (1929), The Roman Military Road System, The Military Engineer, Vol. 21, No. 117, PP. 256-258 .
[8] Joseph Berechman, (2003), P.461.

networks. The extensive and well-maintained road networks of the Roman Empire played a critical role in meeting this demand. [9]

By facilitating the smooth and efficient transport of goods over long distances, these roads enabled people across various cities to access products that were otherwise unavailable to them. This seamless movement of goods not only bolstered trade but also contributed to economic integration and cultural exchange across different regions, reinforcing the interconnectedness of the ancient world. Thus, the sophisticated road network was instrumental not only in military and administrative functions but also in fostering economic growth and cultural connectivity throughout the Roman Empire. [10]
Because of the accessibility of roads, trade could easily be formed between provinces across the country. Foodstuffs (such as meat, fish, cereals, salt, olive oil, wine, and beer) were traded, as were animal products (such as leather and hides), glass, wood, or metal objects, pottery, textiles, and construction and manufacturing materials such as marble, glass, wood, wool, bricks, silver, gold, tin, and copper[11].

Transit tolls were routinely utilized to fund the imperial coffers. For this purpose, the great Roman Empire was split into ten large districts, with customs taxes levied at differing rates on different sorts of goods. In addition to customs charges, transit tolls were collected at specific sites inside these districts[12].

III. Construction Materials

As previously mentioned, the road network was a crucial element in the success of the empire, and it was necessary to provide appropriate construction materials to ensure the quality and durability of these roads. It is curious to ask where the necessary materials for this construction came from? Generally, construction material was obtained locally, from nearby areas, if suitable stone was not available at a nearby site or in the ditches along the road, it was transported from a few miles away. [13]

For example, in stony regions, the stones used for road construction were quarried from nearby areas to create strong foundations for the roads. This approach reflects how adapting to locally available resources reduced the need to transport materials from distant locations, thus lowering costs and effort. Large stones were used in these regions to form the foundational layers of Roman roads, which helped ensure their stability and strength[14].

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[9] Knapton, J., (2016), The Romans and their roads, the original small element pavement technologists, UK, PP.474-476.
[10] Fields, N., & Anderson, D. (2008), P. 86.
[11] Mertens, J., (1955). The Construction of Roman Roads, P. 50.
[12] Hintzen-Bohlem, B., (2000). Art and Architecture in Rome and the Vatican City, Cologne, P.35.
[13] Margary, I.D., (1973). Roman Roads in Britain, London, P.55.
[14] Fair, Mary C. (1927) "Circular Bath-Buildings in Connexion with Cohort Forts." The Journal of Roman Studies 17: PP. 220-224.

Considering the costs and difficulties of long-distance hauling, the essential need to provide construction material from the close areas can explain observed variations in Roman road structure and composition. For example, the rudus, a key layer in Roman road construction, frequently used sand as its primary component in many regions.
In areas where gravel was readily available, it was mixed with sand or clay to form this layer. This localized approach to sourcing materials not only mitigated transportation challenges but also allowed for adaptability in road construction methods based on regional resource availability[15].

Consequently, while Roman roads maintained their fundamental structural integrity and functionality, their construction reflected a pragmatic use of available materials tailored to local conditions.[16].

Indeed, Ancient Roman roads were carefully engineered and often featured various paving techniques, particularly in challenging sections. To create a durable surface, the Romans used gravel when it possible, as a common paving material, which provided stability and a smooth ride. In some cases, flint and other small stones were mixed with the gravel to enhance durability(Figure 2). Stone slabs, introduced in the early 2nd century BC, were also used for paving, offering a more robust surface for high-traffic areas[17].

Additionally, some roads were finished with a form of rough concrete made from a mixture of gravel and mortar, which ensured long-lasting strength and resilience. These diverse paving methods highlight the Romans' skill in adapting construction techniques to different conditions, ensuring that their roads remained effective and durable across the vast empire(Figure 3).

IV. Construction Instruments

For identifying the best axis of the Roman road, they used various tools like:

IV.I Groma

The Groma was used to in drawing of angles. It composes of four branches fixed around metallic column that allow drawing perpendicular from a central point line[18].(Figure 4)

[15] Adam, Jean-Pierre. (1999), Roman Building, Materials and Techniques. London: Routledge, P.66.
[16] Chevallier, R., (1976). Roman Roads. University of California, P.29.
[17] Adam, J.-P., (1999), P. 18.
[18] Richard Adrian, (2009),How Did the Romans Achieve Straight Roads?, Eilat, P.7

IV.II. Chorobates

The chorobates is defined as a massive scale (approximately 6 m) that has been solidified and excavated in its upper section, revealing a water-filled groove. It was utilized to calculate the level of the elevated portions, resulting in a consistent gradient[19].(Figure 5)

IV.III. Odometer

Certain wagons had special perimeter wheels and cogs, which released a tiny stone into a box every Roman mile[20].

IV.IV. Dioptra

Dioptra was an instrument made up of a triangle and a plumb line. It was utilized to level the road. The original interface was simply a horizontal tool made out of an isosceles triangle with a sight at the base. The tip, which has two equal edges is at the bottom and functions as a plumbing benchmark. When aligned with the tip, the view via both eyepieces is completely horizontal[21].(Figure 6-7)

IV.V. Decempeda

The decempeda was a calibrated measuring rod consisting of hardwood and metal ends. It was possibly ten feet long and could be linked to another to give end-to-end measuring.[22]

V. Construction Techniques of Roman Roadways

The Romans were the great builders of ancient times and their road building stand as testament to their advanced building techniques. Their road-building legacy is well-documented both in historical records and through physical examples still visible today.

Notable among these are the Via Appia[23] in Italy and the Via Hadrian[24] in Egypt. These roads exemplify the Romans' commitment to creating a robust infrastructure that facilitated military movements, trade, and administrative efficiency across their vast empire.

By employing diverse paving methods and adapting construction techniques to local conditions, the Romans ensured the longevity and effectiveness of their road network, which played a crucial role in the expansion and consolidation of their empire. Should

[19] Ninouh, T., Rouili, A., (2013), The Protection and Enhancement of the Roman Roads, World Academy of Science, Engineering and Technology International Journal of Civil and Environmental Engineering Vol: 7, No: 12, P.3050.

[20]Richard Adrian, (2009) , P.8

[21] Ninouh, T., Rouili, A., (2013) P.3050.

[22] Richard Adrian, (2009) , P.9

[23] The Appian Way locates in southeast Italy. It was named after the Roman censor Appius Claudius Caecus, who started the construction processes of the road about 312 BC.

[24] The via Hadriana was constructed by the emperor Hadrian in 130 AD, to honor his deceased paramour Antinoos. It was connecting Antinoöpolis with the Red Sea.

advanced civilizations be measured by their transportation infrastructure, Rome stands as a quintessential example. The Roman roads were a testament to Roman power and humanity's capacity to conquer nature. They spoke volumes about Roman culture and their engineering prowess[25].

V.I. Layers Thickness

The road-building techniques of the Romans serve as a solid foundation for modern methods. The core concept involves creating a structure with increasingly robust layers from the subgrade to the surface. The primary distinction lies in the materials employed. Contemporary materials such as asphalt and concrete offer greater convenience in construction than the stone slabs utilized by the Romans(Figure 8).[26]

The construction of Roman roads began with clearing and preparing the site, as a step that is similar to modern construction practices. They cut a trench and that was filled with large stones to create what was known as the *statumen*[27] or foundation layer that provided a solid base for the road(Figure 2-3).

Next, a layer of cemented pebbles and finer stones composing the *ruddus*, this layer considered the intermediate layer served to stabilize the roadbed and provide a transition between the foundational stones and the final surface(Figure 2-3).

On top of the ruddus, a layer of fine cemented sand called the *nucleus*[28] was applied, that helped to create a smooth and even surface, preparing the road for the final course of paving. It followed by the top course of paving stones was called the *pavimentum*[29], which consisted of large, tightly fitted paving stones.[30]

These stones formed the durable surface of the road, and designed to withstand heavy traffic and weather conditions. To ensure the stability of the paving stones and manage water drainage, curb stones were placed along the sides of the road. These curbs helped to keep the paving stones in place and created channels for water runoff(Figure 3).

Roman engineers were also innovative in their use of lime-based cements. They developed technology for producing lime mortar, which was used to strengthen the foundation stones and grout gravel layers within the pavement structure. Lime mortar

[25] Cornelis van Tilburg, (2007), PP.2-3.
[26] Cornelis van Tilburg, (2007), P.16.
[27] Statumen is The first layer a layer that is laid on compacted foundation soil, and consists of large blocks of rocks or stones with a minimum granularity of 5 cm. Worth note that, the layer's thickness varied between 25 - 60 cm.
[28] Nucleus is the third layer; it is about 30 cm thick concrete and composed of cement, sand, and gravel.
[29] Pavimentum is the surface coating and final layer, which is made up of huge 15 cm polygonal and uneven stone slabs that have been skillfully carved to allow for close clamping.
[30] Cornelis van Tilburg, (2007), P.10.

was applied between foundation slabs to create a watertight seal, allowing rougher slabs to be used while ensuring the road's durability[31].

V.II. Compacted Concrete

In ancient construction during the reign of Trajan, there is a notable similarity with modern roller-compacted concrete practices, particularly in the method of compacting materials at a low water-to-cement ratio. Ancient concrete consisted of a mixture of lime, pozzolan and water. The ancient builders hand-mixed their components in a mortar container with very little water to create a nearly dry mix, this mixture was then transported to the construction site in baskets and applied over a prepared layer of rock layer [32].

The ancient technique involved pounding the mortar into the rock layer, a process that closely mirrors modern compaction methods. By tightly packing the material through tamping, the need for excess water was minimized, effectively reducing the water-to-cement ratio and minimizing voids and weaknesses in the concrete[33].

V.III. Road Drainage

Parallel drainage channels, or gutters, were a prominent feature of Roman road construction. In regions in which the level of ground water was higher than usual and prevent constructing stable foundations, the water table had to be lowered to allow digging processes in dry soil.

To ensure their roads functioned effectively across various weather conditions, the Romans implemented a sophisticated system of gutters. These gutters were integral to maintaining the roads' integrity and usability by managing rainwater and preventing water accumulation. They were strategically placed parallel to the road and spaced approximately 40 feet apart to facilitate lateral drainage. By collecting and channeling rainwater away from the road surface, the gutters prevented flooding and erosion that could otherwise compromise the road's structure[34].

This advanced drainage system reflected the Romans' engineering expertise and their commitment to building durable infrastructure that could withstand diverse environmental challenges. Therefore, these gutters were a practical solution incorporated into the road design to enhance the durability and usability of the roads.

[31] Knapton, J., (2016), P. 476.
[32] Duncan-Jones, Richard. (1982). Economy of the Roman Empire. Cambridge University Press, P. 173.
[33] Michael Harold, (2010), Roman Building Materials, Construction Methods and Architecture: The Identity of an Empire, Master of Arts History, Clemson University, PP.16-17.
[34] Cornelis van Tilburg, (2007), PP.19-20.

They complemented the road construction methods by addressing the challenges posed by weather and ensuring that the road remained stable and passable, reflecting the Romans' advanced understanding of infrastructure management. The gutters also served the purpose of providing construction materials. Thus, the ditch functioned as a quarry producing stones and other needed materials which used for paving routes[35].

V.IV. Intentional Ruts

During Emperor Trajan's rule, a notable advancement in Roman road construction was the introduction of intentional ruts, which were grooves deliberately carved into the road surface to enhance functionality and safety. These ruts, ranging from 6 to 30 centimeters in depth, were created using tools such as picks or hammers and were designed to provide better traction for vehicles and horses, preventing slippage and ensuring more stable movement.

This feature was not exclusive to Roman roads; similar grooves were also found on earlier Greek roads, suggesting a transfer of technology or influence between Greek and Roman engineering practices. The deliberate incorporation of these ruts into road design reflects the Romans' advanced understanding of practical road construction, aiming to improve durability and usability across their extensive road network[36].

V.V. Width of the Roads

The ability to maintain the flow of traffic is proportional to the width of roads. A broader route is more effective than a narrower one in reducing traffic congestion. The roman roads weren't had usually the same width; hence not all of them were suitable for all types of congestion. The width was decided based on both factors: the legal status of the road and the local conditions[37].

The Romans employed standard road dimensions. The via, a road suited for all types of traffic, had to be at least 8 feet and reach to 40 feet wide, with bends requiring a minimum width of 16 feet[38]. This width allowed wagons to pass and overtake one another. This norm is often thought to have been stated in the Law of the Twelve Tables since the fifth century BC[39].

V.VI. Courier System

Following the empire's growth under Augustus, Roman road construction peaked during the imperial era. The empire's consolidation increased the importance of Roman

[35] Joseph Berechman, (2003), P.463.
[36] Adam, Jean-Pierre, (1999), P. 32.
[37] Cornelis van Tilburg, (2007), P. 28.
[38] Cornelis van Tilburg, (2007), PP. 25-28.
[39] The Laws of the Twelve Tables were the legislation that served as the foundation of Roman law, which were formally promulgated in 449 BC.

governance, prompting the construction of its infrastructure. This led in the building of a large and high-quality road network that linked even the most remote corners of the empire[40].

Another significant economic consequence of the Roman road system was the establishment of an imperial messenger system, which was most likely initiated by Augustus. Relay sites were set up along the routes, and horses were available to transport riders and carriages for magistrates and court officials. Later, most likely during Hadrian's reign, it became popular for private mail[41].

The majority of road users traveled on foot or horseback. The wealthy and prominent authorities traveled in two or four wheeled carts. As congestion increased, taverns and inns with overnight accommodations were established at every 15 or 20 kilometers regularly along the roadways. Moreover, specific services for changing the horses were developed. Road guides were offered to provide information on routes, inn and tavern locations, and distances[42].

VI. Roads' Maintenance

Maintenance held significant importance for the Greeks and Romans. In order to keep an efficient road network, the government bore the responsibility of funding the upkeep and conservations of the roads.

Military roads were conserved by members of the roman army who were existed in the region or nearby and available to do this work, but if the soldiers were busy, citizens were tasked with the maintenance according to official decrees issued by the governor. Necessary funding was raised either by taxes collected or a private individual. In general, the taxes would be paid on the exports and imports of materials and goods and these revenues were collected while entering cities or crossing the bridges[43].

In the first century, the Julian Law established detailed regulations for the maintenance and repair of city streets, assigning significant responsibility to property owners for the upkeep of roads adjacent to their properties. Under this legislation, owners - whose properties bordered the streets - were required to ensure that their portions of the road remained in good condition. The law also mandated that standing water be prevented on the streets to avoid obstructing pedestrian movement and compromising road functionality.[44]

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[40] Peacock, D.P.S. and V.A. Maxfield, (1997), Mons Claudianus: Survey and Excavation 1987–1993. Cairo, IFAO, 37.

[41] Cornelis van Tilburg, (2007), P.56.

[42] Joseph Berechman, (2003), P.475.

[43] Murray, G. W. (1925), The Roman Roads and Stations in the Eastern Desert of Egypt. The Journal of Egyptian Archaeology 11: 3/4, P. 140.

[44] Cornelis van Tilburg, (2007), PP.128-130.

Furthermore, the law specified that each owner whose premises directly about the road or sidewalk was responsible for keeping their drains free-flowing until they connected with a main drain. In cases where an owner failed to meet these obligations, the city would appoint a contractor to perform the necessary repairs and charge the cost to the defaulting owner, potentially adding a fine. The process included a ten-day notice period and the public posting of a notice naming the street and the responsible front-of-house owner. This comprehensive approach not only ensured the maintenance of infrastructure but also promoted accountability and public awareness.[45]

Additionally, most streets were constructed from stone blocks laid flexibly, which were expected to be kept clean. So, Street commissioners were appointed to oversee maintenance within their designated areas, often utilized enslaved labor. While some rulers took the maintenance of streets more seriously than others, as Emperor Vespasian who notably repaired Roman streets at his own expense when it decayed due to previous neglect.

The maintenance of ancient Roman roads required a rigorous approach to ensure operational efficiency and safety. It was essential to maintain the road's designated width, keep it free from obstacles, and ensure thorough cleanliness. Judges held the authority to mandate road paving and enforce regulations to uphold road quality and the Local laws strictly prohibited any excavation or construction on the roads, with violators facing legal penalties and fines[46].

According to a local statement, no one was permitted to dig trenches or erect structures on the roads. Anyone found to be in violation of these regulations faced fines and sometimes was prisoned. Furthermore, the rule declared that no one was authorized to establish a lower-quality road under the pretext of restoring it[47].

In conclusion, Julian's law was also concerned with maintaining the cleanliness of streets, assigning the responsibility of appointing street sweepers to the city council. Additionally, the law imposed strict regulations against disruptive behaviors, such as fighting in the streets, and prohibited the public from disposing of waste or dead animals on the roads. Such measures were intended to prevent obstructions, ensure safety, and maintain a clean environment, reflecting the Romans' commitment to preserving the functionality and integrity of their urban infrastructure.[48]

[45] Hardy, E.G., (1975), 'Roman laws and charters', New York, P.136.
[46] Cornelis van Tilburg, (2007), P.40.
[47] Duncan-Jones, R, (1982), P.174.
[48] Cornelis van Tilburg, (2007), PP.128-130.

VII. Sustainability of the Roman Roads

In cultures with city-states, such as the ancient Greece, the roadways were shorter, less developed and most of the time not paved. Because of rivalry among these societies, it wasn't essential to create an intelligible road system.

Unlike the Greeks, the Romans had progressed from the city-state concept to the Empire and the construction of roads was based on this expansion. When the Romans began the conquest of Italy in the 4th century BC, they constructed a straight and paved road network either outside or inside their colonies, settlements, villages and cities, allowing rapid movements of the army and enhancing trade movement(Figure 1).

The road networks are regarded as one of the Roman Empire's greatest legacies. From Rome to Egypt and everywhere else throughout the empire, there are such remains of these iconic landmarks have lasted to this day, in some cases even serving the foundation for modern roads today, e.g., the well-known via Appian in Italy and via Hadrian in Egypt.

VII.I. Via Appian

Appian Way is the oldest road of the Romans and functioned as an important access route into the city of Rome. Originally, the route extended all the way to Brundisium in Italy[49].(Figure 9)

The road was named after Appius Claudius Caecus who authorized its building at the end of the 4th century BC, mostly in 312 BC. The road prime purpose was to move legions of soliders more rapidly during the war; nevertheless it was also utilized for shipping goods and supplies, as well as to facilitate economic trade movement with Greece, Egypt and North Africa[50].

The paved stone road was known as "regina viarium"; which means "queen of the roads", due to its significance and beauty. Worthy talking that Part of the road, starting at the Cecelia Metella funerary monument, still contains old paving gravels that obviously display the wear of the carriage tracks[51].

The Appian Way is exceptionally well-preserved, especially when compared to many Rome's other best attractions. It's constructed of enormous, flat stones that have been firmly anchored by more than two thousand year of rain, wheels and passing feet over them. When you touch them, you are following the footsteps of roman emperors, soliders, and merchants.(Figure 10)

[49] Joseph Berechman, (2003), PP.454-455.
[50] Ivana Deila, (2004), The Appian Way from Its Foundation to the Middle Age, Los Anglos, PP. 11-12.
[51] Joseph Berechman, (2003), P.453.

Via Appian also gives traces of the Roman innovation in road construction. Until then, roadways were hardly more than mud or dirt paths that became impractical for wheeled vehicles with every rainfall. The paved roads allowed them to construct a large network that has stayed intact for centuries and serves as the backbone for all the Mediterranean countries' road systems. Furthermore its significance in the history of architectural restoration stems from the numerous efforts to reclaim and restore it beginning in the 16th century[52].

Owing to the former outstanding universal values, which need to be acknowledged, preserved and transmitted to future generations, for learning and enjoyment, the UNESCO paid a great attention to the road and acknowledged it to be among its tentative list in preparation for being inscribed on the world Heritage List.

VII.II. Via Hadrian

The Roman Emperor Hadrian (117-138 AD) built Via Nova Hadrian as a new road from Antinoöpolis to Berenike on the Red Sea in Egypt mostly about 137 AD [53] and considered the longest roman road in the eastern desert (about 800 Km) (Figure 11). The Via Hadrian survives in quite good condition as it traverses the desert between Antinoöpolis and coast of the Red Sea in the eastern desert. A number of ancient roman roads crisscrossed Via Nova Hadriana at certain points along its course.

While most of the roads in the eastern desert served as communication networks for military, commercial and control objectives, Hadrian road appears to have been functioned mainly as an administrative route. Because of the length of the road would not have suitable for merchants that moving goods between the Nile valley and the ports of the Red Sea; the more southerly roads were better position and more direct for those purposes.

These other roads appear to predate construction of Via Hadrian and were main routes joining the Nile valley to the Red Sea coast, such as Myos Hormos- Coptos road that linked Marsa Nechesia on the coast to Apollonopolis Magna on the Nile, or the road connecting Berenike to Edfu and then later to Coptos on the Nile.

Along the roadway across the desert between Antinoöpolis and the coast of Red Sea, most stations[54] and the route itself survive in relatively good conditions of preservation although the fact that those water stops had little considerable architecture related with them at any point in their history.

[52] Willem Tielen, (2022), The Via Appia in transformation – visitor's perceptions and heritage-formation 1849-1853.

[53] Murray, G. W. (1925), P. 149.

[54] In Roman times all these main routes across the Eastern Desert were fortified with wells and small military forts to provide places to rest for caravans and travellers, exercise control over the traffic, assist the exchange of messages and provide security.

The fine preservation is definitely due to the general isolation of the road sectors, wells, and stations from any recent areas of habitation and to the fact that the road and stations in this region are not exposed to the identical intense waterborne seyul that happen along the coastline[55].

Two best survived examples of such an unfortified stop stations on this east-west part of the road is at Makhareg about 40 km east of Antinoöpolis, and the road station at the Roman site of Umm Suwagi, about 110 km east-northeast of Antinoöpolis and 70 km from Makhareg[56].

Unlike Via Appian, Via Hadrian has not been acknowledged within the UNESCO tentative list of the world Heritage sites until now. When a country signs the World Heritage Association, and has sites acknowledged on the World Heritage List, the subsequent approach frequently raises awareness among residents and governments for heritage protection. The World Heritage Committee may also provide the country with financial funding and expert advice from to support activities aimed at preserving its properties [57].

Conclusion

From the previous, the following points can be concluded:

1) Road networks contribute to economic progress and development, providing significant social, political and military benefits. They play an important role in the growth and development of nations. For these reasons, road construction is the supreme important of all public assets.
2) The Roman roads stand as a testimony to ancient engineering skill. Their longevity heritage assists as an indicator that shed the light on smart design, high-quality materials, and careful maintenance that are essential for durability and longevity of the road.
3) The longevity and sustainability of the ancient Roman roads is extraordinary. Some have survived for centuries without serious maintenance, due to various contributing factors including:
    a) Quality Materials: Durable lime mortar, as well as well-fitted stones.
    b) Maintenance: Skilled laborers perform regular maintenance for timely repairs.

[55] Sidebotham, S., Ronald, E., (2000), Survey of the Via Hadriana: The 1998 Season, Journal of the American Research Center in Egypt 37: PP. 115-126.

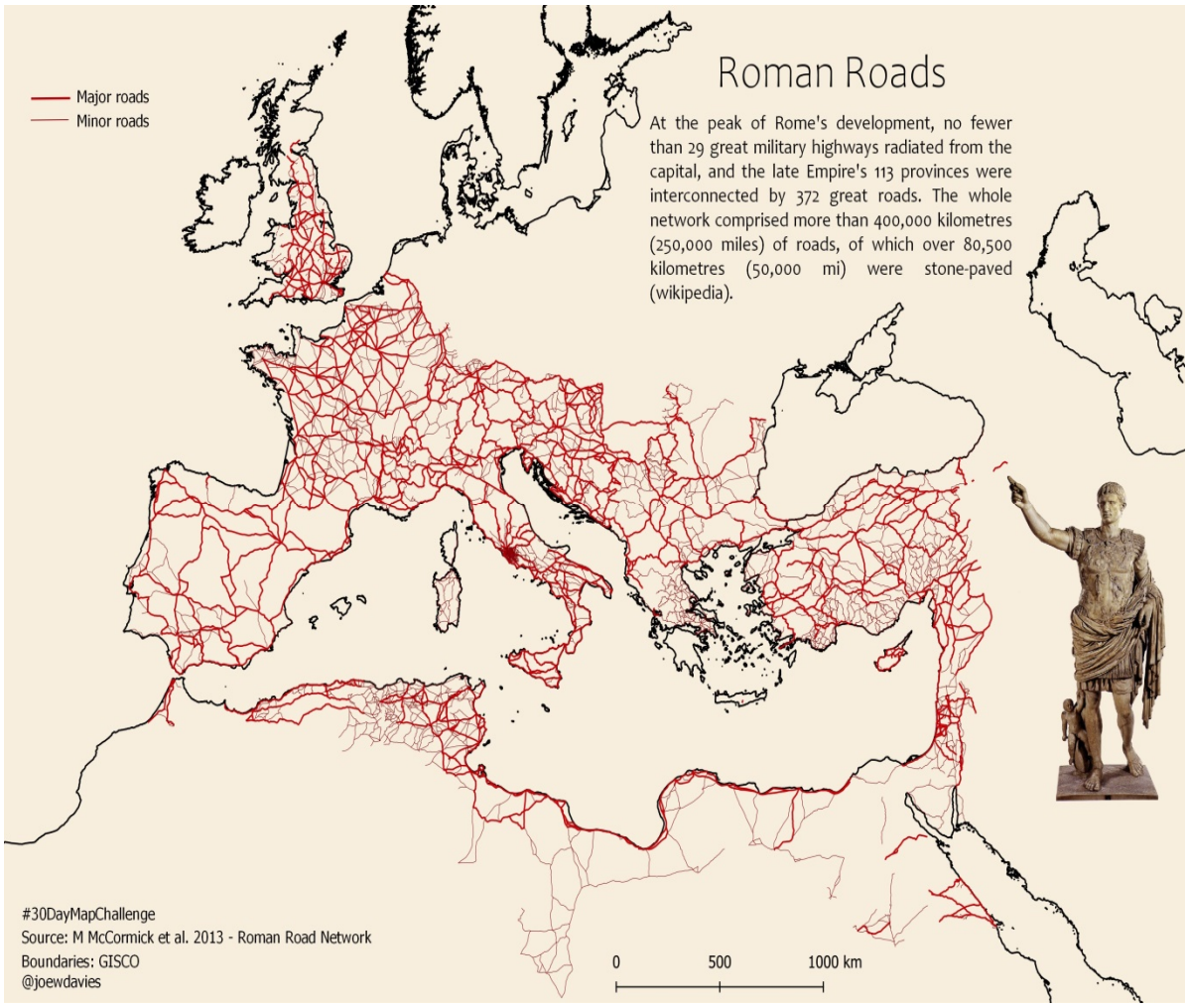
[56] Sidebotham, E., Hense, M., (2008), The Red Land: The Illustrated Archaeology of Egypt's Eastern Desert, AUC Press, P.51

[57] The official website of UNESCO. https://whc.unesco.org/en/faq/20 , (Accessed: 5th of July 5:52 PM.)

c) Drainage: Effective drainage systems avoid accumulation of water and erosion.
d) Load Distribution: The multilayer design distributes weight evenly, decreasing wear and tear.

4) The UNESCO pays much attention, support and fund to the sites that represent such durable and longitude constructions or extraordinary examples of architectural design that shows important phases of the history and indicates of human creative genius.

List of Figures



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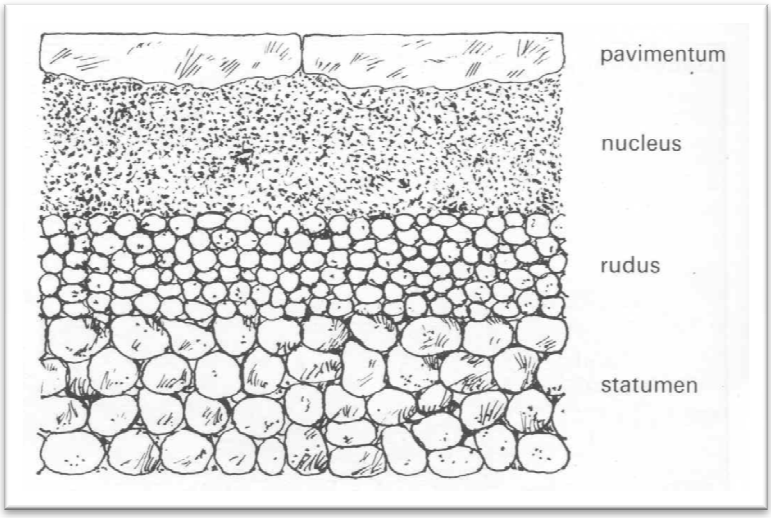

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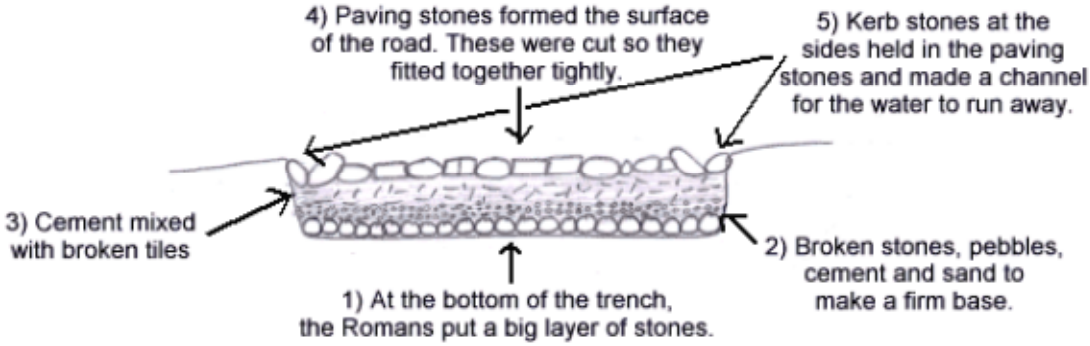

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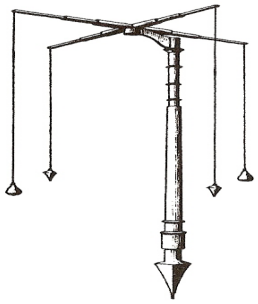

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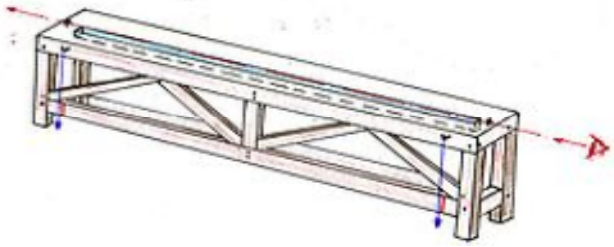

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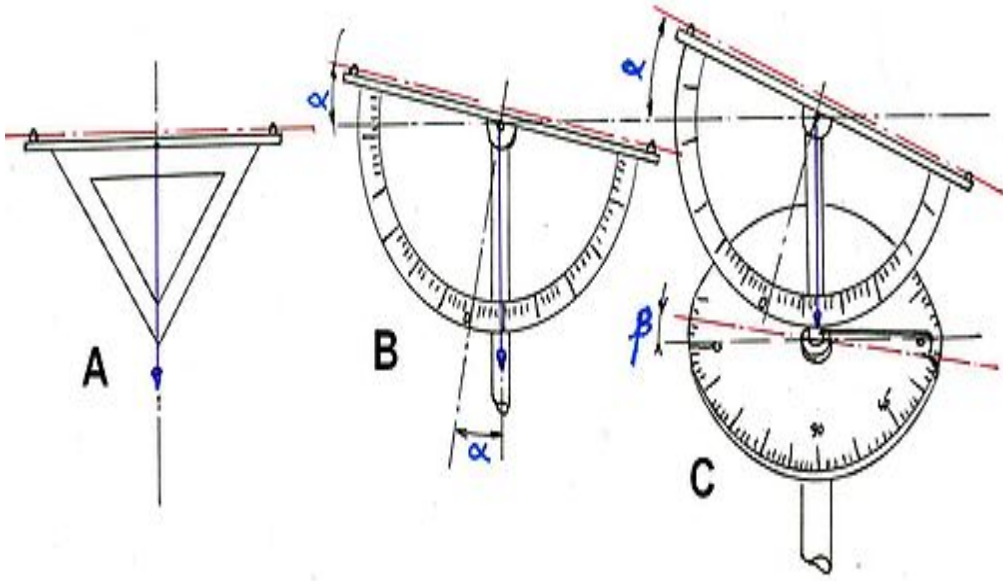

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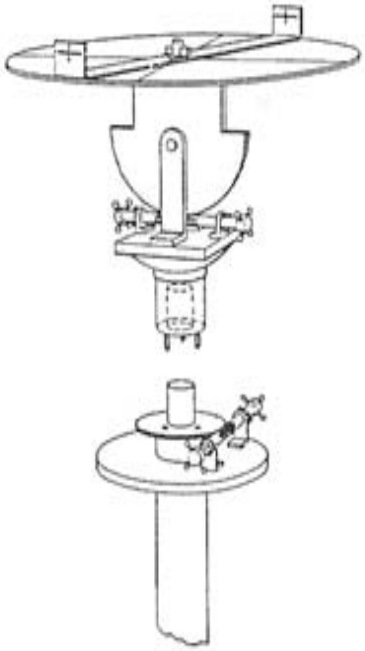

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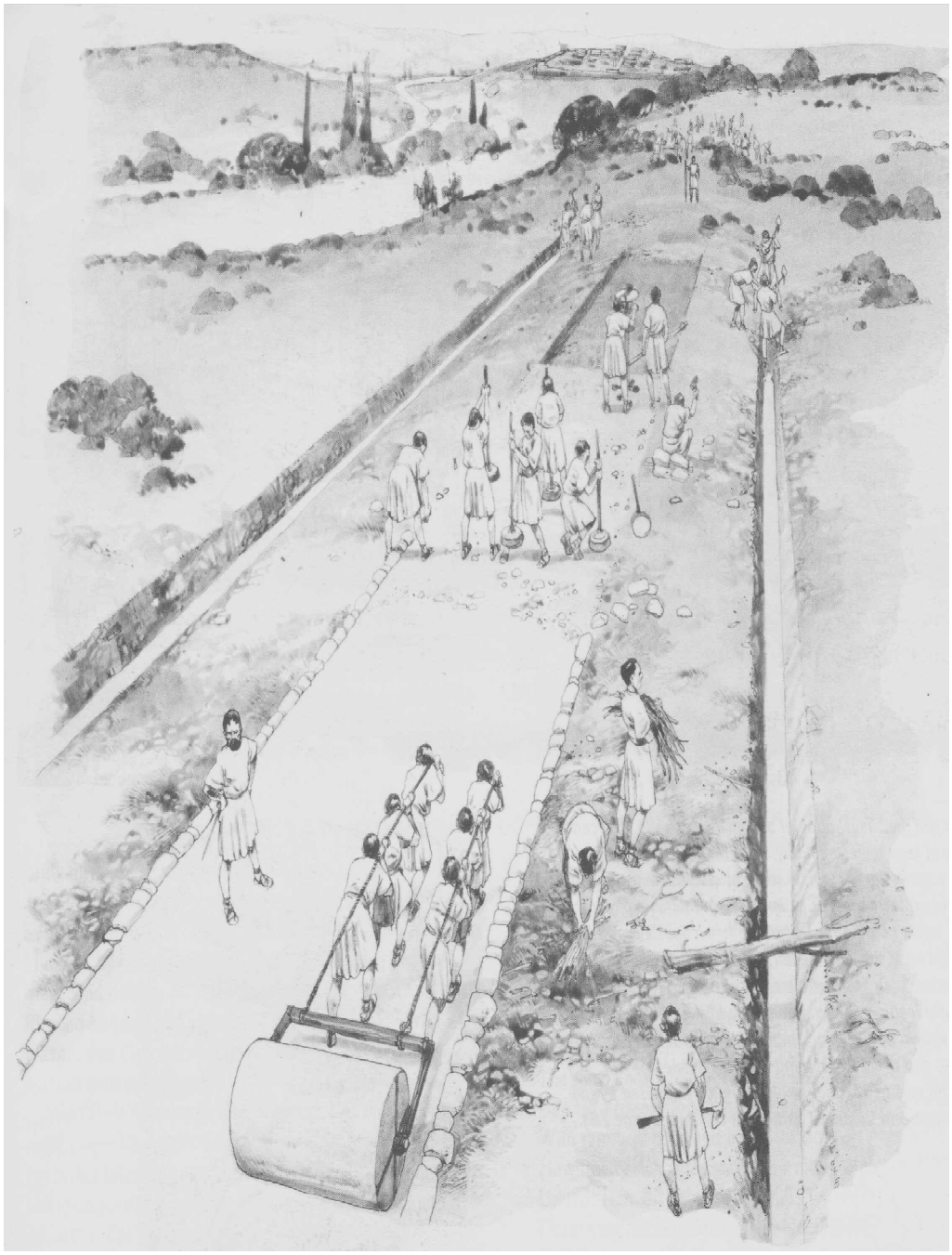

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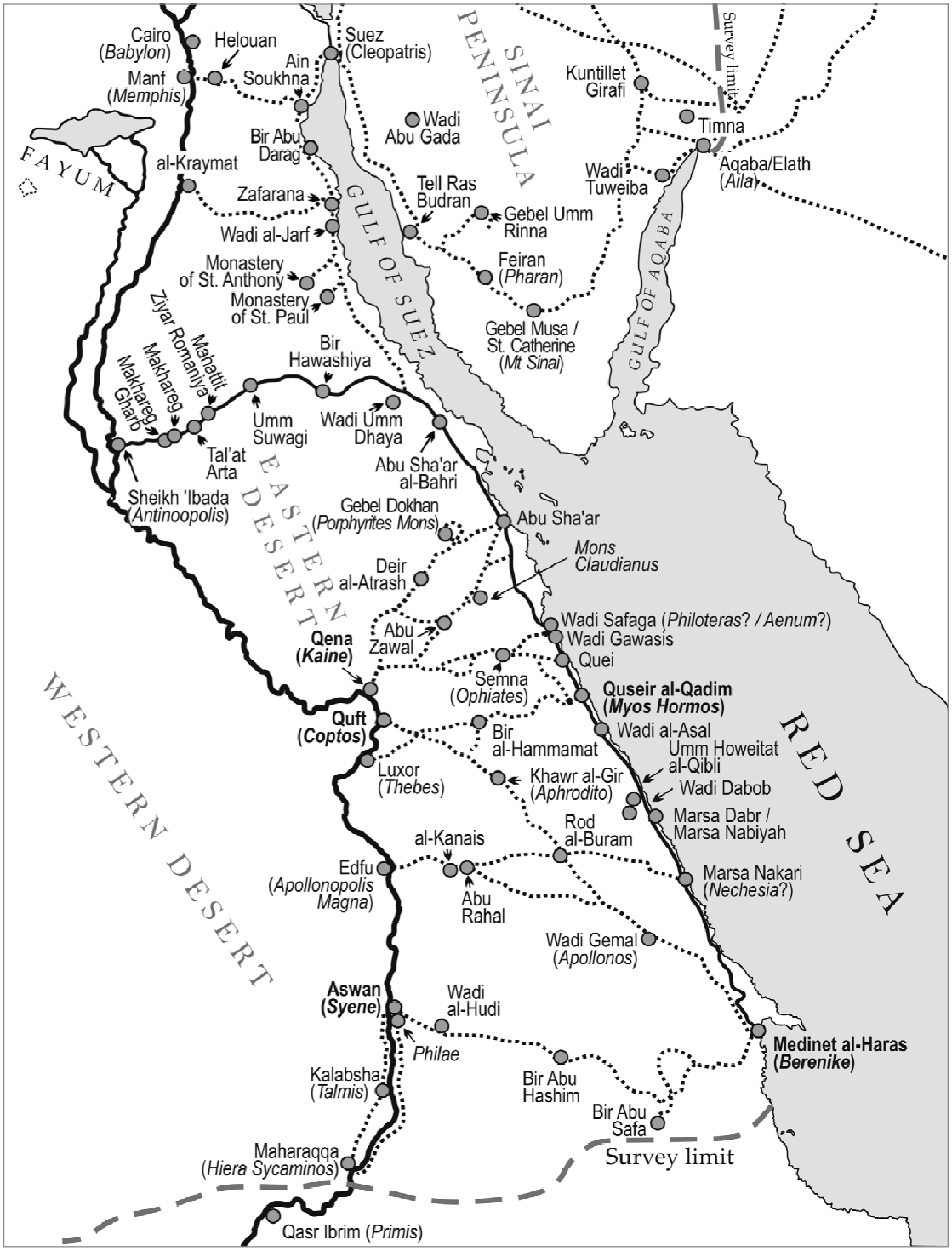

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دور تقنيات البناء الرومانية في إستدامة نظام الطرق في الإمبراطورية الرومانية

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الملخص العربي

تعتبر الطرق الرومانية على خير دليل علي توظيف مهارات الهندسة المدنية في خدمة الإمبراطورية حيث شهد بناء شبكات الطرق أنواعاً عديدة من التقدم والتطور ظهرتجليةً في تعدد وسُمك طبقات الطرق واستخدام انواع مختلفة الخرسانة المضغوطة، كذلك إنشاء نظام للصرف الصحي والأخاديد لتصريف المياه، وليس ذلك فحسب بل واهتموا أيضاً بعرض وإتساع الطرق واخيراً استحداث نظام البريد السريع . لكن الفترة التي شهدت ذروة الاهتمام بمرافق الطرق كانت في عهد الامبراطور أغسطس (27 ق.م - 14 م) وتراجان (98 - 117 م) وهادريان (117 - 138 م) كما شهدت الكثير من التحول في شبكات الطرق.

تشتهر شبكات الطرق الرومانية بمتانتها وكفاءتها الهندسية، فعلى الرغم من أن عمرها يزيد عن ألفي عام، إلا أن العديد من هذه الطرق القديمة لا تزال موجودة وبعضها مستخدم حتي يومنا هذا، على سبيل المثال طريق أبيان الشهير في إيطاليا وطريق هادريان في مصر. في المقابل، غالبًا ما تتطلب الطرق الحديثة إصلاحات وصيانة ليس بعد وقت طويل من إنشائها. إذن، ما هي الأسباب الرئيسية لهذه المشاريع الضخمة والمكلفة؟ وما الذي يجعل هذه الطرق الرومانية طويلة الأمد؟ هذه هي الأسئلة الرئيسية التي يهدف هذا البحث إلى التحقيق فيها. علاوة على ذلك، يهدف هذا البحث إلي التوعية بأهمية شبكات الطرق الرومانية، وكذلك تشجيع الجهات المعنية على ترميم وصيانة هذه الطرق وتحسينها لأن التحضر المعاصر أو مجرد النسيان، يهدد استدامة هذا التراث التاريخي الهام.

الكلمات الدالة: مصر الرومانية – شبكات الطرق – مواد البناء – تقنيات البناء – الاستدامة