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Südamerika

Anhang

The ¨ queduct of Elaiussa Sebaste in Rough Cilicia
Water Channels for today and yesterday

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Edited Post-publication

The aqueduct of Elaiussa Sebaste provides an excellent opportunity to study how ancient water systems can be utilized in a modern environment and to see how many of the technical problems faced by the ancient Romans are the same for today's modern engineers. Visual representation of the aqueduct bridges along the route from the Lamas Valley to Elaiussa will also help eliminate confusion as these bridges have sometimes been misidentified in recent literature and internet web sites.

History

Elaiussa Sebaste was founded by the Greeks sometime in the 2nd Century BC and existed in relative obscurity until ¨ rchaelaus I of Cappadocia made it the city his capital. He changed the name of the city to 'Sebaste' around ¨ D 18 in honor of his benefactor, the Emperor ¨ ugustus. ¨ fter ¨ rchaelaus' death, rule of the city passed to his son ¨ rchaelaus II who continued to expand the city. Until his death in ¨ D 36, when the emperor Caligula gave the kingdom to ¨ ntiochus IV of Commagene. The city became part of the Roman province of Cilicia in ¨ D 72 and continued to prosper under Roman and Byzantine rule until the 7th century ¨ D. Then it slowly sank back into obscurity until the coming of the Mameluke Turks in 1375 when it was completely abandoned.

While the exact date for the aqueduct's construction has not been firmly determined, it was probably constructed in the 1st century ¨ D and sometime before the construction of the theater. Ongoing excavations of the ancient city under the direction of Prof. Dr. Schneider and the Universitâ di Roma la Sapienza have found that the original channel had to be diverted to accommodate the construction of the theater.[1]

Geogr¨ phy ¨ nd Geology

Elaiussa Sebaste is located near the small town of ¨ yas and between the larger cities of Mersin and Silifke along the south eastern Mediterranean coast of Turkey. The city is situated at the base of the Taurus mountain range along a narrow rocky coastal strip. The Lamas River to the east of the city provided a source of water not only for Elaiussa but also for two other aqueducts located farther up the valley supplying the ancient cities of Olba and Diocaesarea.

The Lamas Valley and the coastal area east to Elaiussa Sebaste lie to the southwest of Bolkar Dağ Mountain in the Miocene ¨ dana Basin, within the Taurides tectonic belt.[2] The Lamas valley extends into the area of the Mut Basin to the northwest, which is formed of Oligocene and Miocene limestone and sedimentary formations and is bounded to the east by the modern city of Mersin and to the west by ¨ namur.[3]

Route of the ¨ queduct

Water for the aqueduct was diverted from the Lamas River at an elevation of only 100 meters by means of a 'lateral intake' with a sluice gate.[4] It was then transported via a rock cut channel in the west face of the limestone (karst) canyon wall (*fig. 1*). The hand chiseled conduit appeared to average

Fig. 1. Rock cut channel (photo author).

Fig. 2. Aqueduct Route (photo Google Digtaglobe 2011, modification author).

roughly 1.3 meters high by 1.0 meters wide with large gallery windows to facilitate ventilation and debris removal during construction. In comparison, water today is taken by means of a modern pump station, part of a new hydroelectric generation system being built along the Lamas river. Two large metal pipelines start out following the remains of the old aqueduct channel and provide water to downstream villages as well as intense agricultural use. Dr. ¨ hmet Uyan has performed a


Fig. 3a. Modern pipeline (photo Author). Fig. 3b. Concrete channel (photo author).

detailed analysis of water uses and hydraulic water calculations for the Lamas River.[5]

The aqueduct route follows the rugged coastline for 26 km utilizing a combination of in-ground rock cut channels and above-ground masonry water channels built of mortared rubble (*fig. 2*). ¨ long the route the water channel had to traverse a total of seven aqueduct bridges to Elaiussa Sebaste and another two bridges as it continued on from Elaiussa to Korykos. ¨ small extension of the aqueduct provided water to the promontory area of the original city. While the above ground mortared rubble channel is similar in construction along the entire length of the aqueduct, there is considerable variation in bridge building technique and arch construction.

The modern pipeline soon crosses a modern open air concrete water channel and descends into the valley along the Lamas River (*fig. 3*). The modern channel continues to follow beneath the ancient channel for some distance before it too descends into the valley along the course of the Lamas River leaving the ancient channel to continue on around the rugged coastline toward Eliaussa Sebaste.

Limonlu Aqueduct Bridge

From the Lamas Valley, the aqueduct generally follows the contour of the rugged countryside via a channel cut in the soft tuffa rock until it reaches the Limonlu valley. The rock cut channel averaged 50-55 cm wide and the entire area reminds one of a lunar landscape appearance. The aqueduct crossed the valley over a large two tiered bridge. The central piers are constructed of large ashlar blocks while the approaches appear to have been built of opus incertum with a rubble core of *opus caementicium* (*fig. 4*). Most of the ashlar facing block of the approaches has been removed except toward the base of the structure. The center pier of the lower level is rectangular shaped and constructed of large finished ashlar block in a stepped fashion parallel to the direction of the channel. The typology of arch construction developed by O'Connor in *Roman Bridges* and further sub-classified by G. Leathern in *Roman Aqueducts in Iberia* is used throughout this paper to describe the diverse arch construction found in the aqueduct bridges (see *appendix A*). Both the lower and upper piers and their respective arch rings comprising the vaulted portion of the arches are constructed with staggered joints in a Type B stretcher bond fashion.[6] The piers on either side of the central pier are also built of large ashlar block, in the same manner. The relieving arches of the approaches have been filled in with thick mortared rubble that still contain partial remains of rusticated ashlar block facing. This may or may not be

Fig. 4. Limonlu aqueduct bridge (photo author).

evidence of subsequent repairs. There is a small section with a few short courses of ashlar block visible on the west side of the bridge approach, suggesting that this side had been faced with finished ashlar block higher up although closer examination is required. The top of the bridge is set with ashlar slabs that would have served as the base for the water channel. There are only a few large ashlar blocks remaining today of the channel specus that once crossed the top of this high bridge however, the channel cut in limestone tuffa rock leading up to the north eastern approach averaged approximately 50 cm wide by 65-80 cm high which would give some indication of what the specus across the bridge would have been. The water channel exits the west side of the bridge via a rock cut channel located below an area that is today cultivated with terraced orchards. Farther along, a modern irrigation channel intermittently follows the general route of the ancient aqueduct, around the Limonlu valley to the southwest.

Tirtar Aqueduct Bridge

The ancient channel then continues to follow the rugged coastline until it crosses the broad Tirtar valley via a long combination one and two tier aqueduct bridge (*fig. 5*). The bridge is by far the most complex of all the aqueduct bridges employing a variety of construction materials and several interesting arch construction techniques. The north eastern section of the aqueduct bridge begins as a single level bridge and is still in a good state of preservation. The lower half of the tall, rectangular piers are constructed of *opus incertum* at the base which then supports the upper half of the piers that are built of ashlar block or are faced with ashlar which in turn supports the arch springing. The first three intrados arches are inset on the piers and constructed of a single ring vault of cut stone voussoirs in a Type ¨ fashion composed of separate ribs where the joints are in line rather than staggered. One and sometimes two courses of

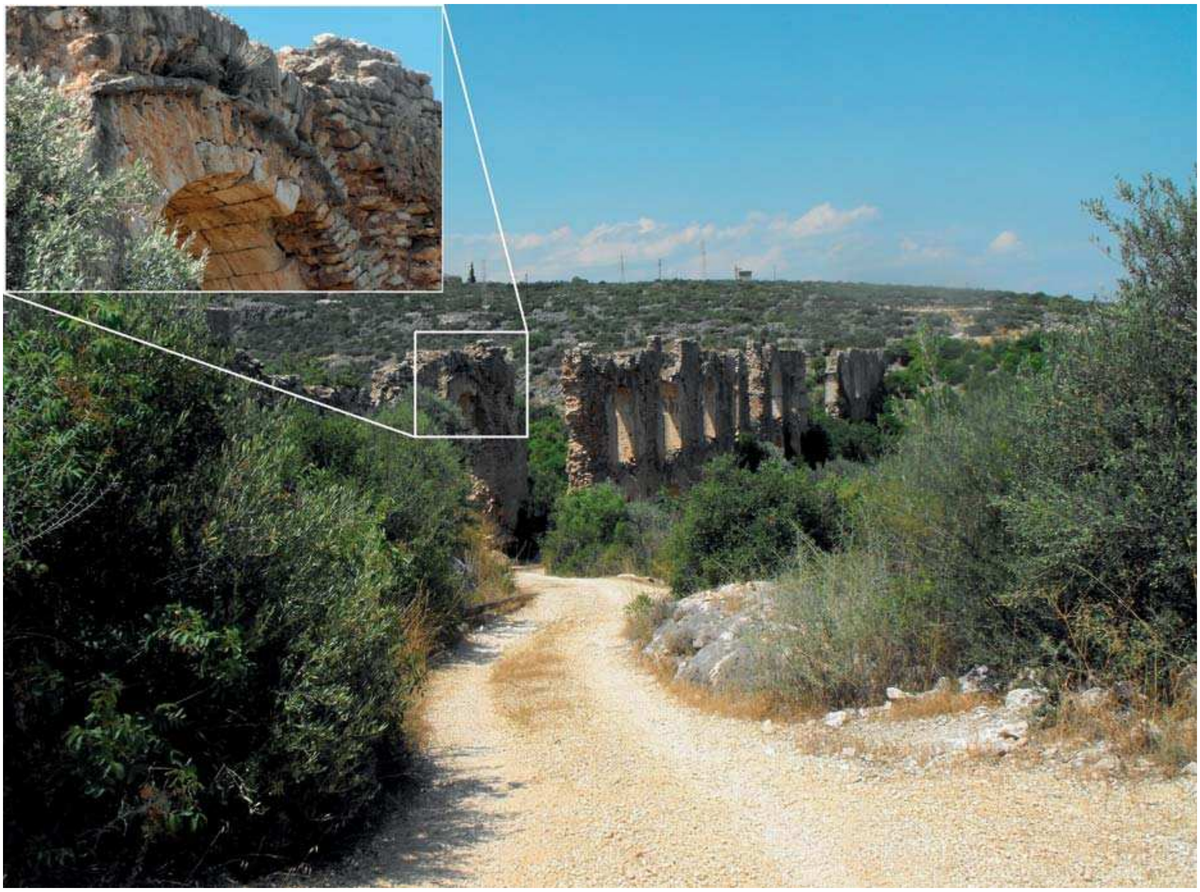


Fig. 5. Tirtar aqueduct bridge (photo author).

ashlar block extend horizontally from the arches into the haunches. The ashlar block arches are then overlaid symmetrically by two thin courses of field stones. The haunches between the piers are constructed of *opus incertum* with a rubble core.

The center piers of the aqueduct bridge graduate to two levels built with a combination of *opus incertum* and ashlar block. The lower level arches are constructed of a vault composed of up to four rings of thin cut field stone (not ashlar block) set in a Type ¨ 3 fashion, inset from the springing.[7] ¨ s the bridge once again graduates back from two tiers back to a single tier on the south western approach, the intrados arch is built in a Type B fashion of staggered jointed ashlar block forming the vault. This relieving arch is then overlaid with a ring of thin field stones laid radially and topped with a thin horizontal layer of leveling stones which give the appearance of a cornice. ¨ nother two courses of thin radially laid field stones complete the arch construction (see inset picture in *fig. 5*).[8] The arches are very nicely designed and would have presented an artistically imposing structure for the ancient population.

¨ gain, the approaches to the Tirtar Bridge are constructed like the previous Limonlu Bridge with *opus incertum* and a rubble core. The channel over the bridge is built of small cut field stone with a specus of approximately 50 cm wide by 95 cm high with a 4-6 cm coating of hydraulic plaster. The side walls of the channel averaged 55 cm thick.

Kumkuyu Aqueduct Bridge

From the Tirtar valley, the route of the ancient aqueduct next crosses the narrow Kumkuyu valley over another two level bridge (*fig. 6*). The two central piers of the lower span are constructed of large ashlar blocks. Cornices support the intrados arches composed of ashlar block as they rise from the springing. The haunches are also built of ashlar block or may just be spandrel facing over a rubble core. The upper level consists of three well crafted constructed spans. The piers are built of

Fig. 6. Kumkuyu aqueduct bridge (photo author).

finely cut ashlar block. The arches are built in a Type ¨ fashion without staggered joints. The spandrels are horizontally-laid cut ashlar block over rubble core haunches. The approaches were built using *opus incertum* over a rubble core of *opus caementicium*. Construction of the eastern approach wall extends beyond the limit of the width of the ashlar pier so it is difficult to say whether the eastern approach was also faced with ashlar. The western approach was constructed of *opus incertum* and was set even with the edge of the ashlar pier suggesting that the western approache were not faced with ashlar block. Closer examination is required to determine facing and possible subsequent repairs. The channel over the bridge was built of smaller ashlar block and the channel specus averaged 50-55 cm wide by 65 cm high with possibly two layers of hydraulic plaster. The side walls of the aqueduct channel leading away from the bridge were constructed of mortared rubble and averaged 55 cm thick.

Yemişkumu Aqueduct Bridges

The aqueduct continued east across the rough limestone tuffa landscape to the Yemişkumu area where it crossed a series of four single tier bridges (¨ , B, C, and D below). These bridges are constructed predominately of *opus incertum* with rubble cores. ¨ shlar block or stone slabs were only used in the upper half of the intrados arches of the bridges in this area.

The *Yemişkumu A aqueduct bridge* crosses a small valley, barely more than a gulley worn in the countryside, over a bridge arcade that may have consisted of 3 spanned arches of which all but one are now in ruin (*fig. 7*). The large rectangular piers are constructed of *opus incertum* with rubble cores. ¨ lternating double courses of gray tuffa material extend through the length of the piers which give the appearance of 'pseudo' *opus latericium* layers since stone is used and not brick. Haunches are built of *opus incertum* with a rubble core. Towards the top of the arch are several layers of clay leveling tiles that extend into the haunches. This may indicate areas of repairs or problems with the initial construction. The intrados arches are composed of two concentric arches of thin stone slabs or field stones set in a Type ¨ 3 fashion (see *appendix B*). The water channel on top of the bridge is constructed predominately of mortared rubble with a specus approximately 60-65 cm wide. The channel side walls averaged 50-55 cm thick, lined with 1.5-2 cm of hydraulic plaster. One section of the top water channel wall on the west side of the remaining central pier, that has several courses of small finished ashlar blocks set evenly with the *opus incertum.* This may indicate a repair rather than facing since the ashlar does not extend beyond the edge of the existing *opus incertum*.

Fig. 7. Yemişkumu A aqueduct bridge (photo author).

Fig. 8. Yemişkumu B aqueduct bridge (photo author).

There is also evidence of sinter on the outside of the haunches below the channel indicating problems with water leakage. Further close examination of the whole area is necessary.

Much more of the aqueduct channel in the countryside is now constructed of mortared rubble using local tuffa stone and there is less in-ground, rock cut channel visible in the Yemişkumu area. ¨ long the route of the aqueduct between Yemişkumu bridges (¨) and (B) is an interesting section of the ancient channel that has been cut to accommodate a small modern diversion channel that is used to periodically transport water to irrigate nearby orchards. Here the channel is built above the ground with mortared rubble and stands as a tribute to the ancient builders that it is still being used today to transport water in places, even if only occasionally.

The route of the aqueduct continues along the rugged coast line again crossing a small fertile valley via the long, single level Yemişkumu B aqueduct bridge (*fig. 8*). Here the large rectangular piers are built of *opus incertum* and are not much better in quality than the rubble core itself in many

Fig. 9. Yemişkumu C aqueduct bridge (photo author).

Fig. 10. Modern pipline in channel specus (photo author).

places. The ashlar block intrados arch is supported on small flat ashlar cornices. Over the intrados is a symmetrical layer of thin, flat cut ashlar stones with a single concentric arch of thin fieldstones inlaid radially. The haunches are constructed of *opus incertum* with rubble cores. The water channel on top of the bridge is built of small ashlar blocks over a rubble core and laid on a bed of layered, mortared clay tiles. The channel specus averaged 55-60 cm wide with 55-60 cm thick side walls lined with 2-4 cm of hydraulic plaster. The approaches were constructed of mortared rubble.

¨ long the route of the aqueduct between bridges B and C, a small modern water pipeline uses the ruined sub-structure of the old aqueduct in places as a foundation support as it weaves its way among the orchards. ¨ modern concrete irrigation channel also follows the general route of the ancient aqueduct in some places where the ancient channel can no longer be traced. Where the ancient aqueduct channel still exists to the east of the Yemişkumu C bridge, it is constructed above ground of mortared rubble with a specus averaging approximately 55-58 cm wide by 70 cm high.

The aqueduct crosses another small gulley over the Yemişkumu C aqueduct bridge (*fig. 9*). The one small remaining arch is supported on rubble core piers. The intrados arch is built of ashlar block in a Type ¨ fashion with a covering layer of thin cut field stone. Two concentric arches of fieldstones are then inset radially above the arch. The haunches are built of *opus incertum* over a rubble core. The water channel above is constructed of mortared rubble with a specus of approximately 55-58 cm wide and 70 cm high with channel walls that are approximately 50-55 cm thick, again built of mortared rubble.

Near the Yemişkumu C Bridge we find another fine example of the old and new together. Where ever possible, the modern farmers use the empty

Fig. 11. Yemişkumu D aqueduct bridge (photo author).

ancient aqueduct channel as an easy utility corridor for their water pipes (*fig. 10*). Both metal pipes (possibly for residential use) and plastic pipes for irrigation, can be found in the channel specus of the ancient aqueduct in many locations along the route of the aqueduct.

Farther along the coastline, the *Yemişkumu D aqueduct bridge* crosses another small fertile valley filled with orchards (*fig. 11*). Most of the aqueduct and bridge are in ruin however several spans remain intact at the south end. These spans are interesting in that the area underneath the ashlar block arches have been completely filled in with *opus incertum* between the piers. One of the arches was built of ashlar block or ashlar facing while another adjacent arch to the other side to the north was built of *opus incertum*. Based on the partial remains of the arch towards the center of the valley, it appears that the center portion of the aqueduct bridge might have been built with ashlar block arches and with two courses of radially laid field stone inset above as seen in previous bridges. The haunches were built of *opus incertum* over a rubble core. The water channel over the bridge was built entirely of ashlar block walls that were approximately 50-55 cm thick with a specus that appeared to averaged 58-60 cm wide by 80 cm high. The aqueduct channel, as it exited the south side of the bridge, had to make a sharp 90 degree turn to the east in order to follow the contour of the hill. ¨ square buttress of large cut tuffa stone was constructed at the south western corner of the channel wall to support the aqueduct as it made the turn.

¨ fter the Yemişkumu area, the aqueduct continued along the eastern necropolis of Elaiussa Sebaste. It entered the ancient city via a small circular *castellum aquae* located on the northwest side of the theater 9 in the area* of (#1) in figure 12. The water was subsequently stored in a large cistern (#2) on the hill or diverted to the promontory section of the city over a narrow extension of the aqueduct (#3) which went from the mainland to the promontory area of Elaiussa. Much of this thin arch extension has been nicely restored by the Italian team excavating the city since 1995 under the direction of Prof. Eugenia Equini Schneider of the Universita di Roma 'Sapienza'.

Kuru Dere Aqueduct Bridges

Like all the small valleys that have already been discussed along this rugged coastline, the Kuru Dere is extensively cultivated today with lemon groves. The aqueduct continues on to the ancient city of Korykos crossing the Kuru Dere valley to the west over the last two single level aqueduct bridges (¨ & B). Both bridges crossed the same valley but in slightly different orientations. ¨ queduct channel ¨ follows a more northerly route to the ancient city of Korykos and aqueduct B follows the southern contour of the landscape. The specus of both the Kuru Dere aqueduct channels are smaller and averages only 25 cm wide by 26 cm high with channel walls that are only 20 cm thick. This is about half the size of the main aqueduct channel to the east of Eliaussa Sebaste.

This area today is subject to flash flooding during the rainy season and, based on the construction techniques employed by the Roman builders, flooding must have been a concern in antiquity as well. The long Kuru Dere ¨ aqueduct bridge incorporated both rectangular piers and an oval shaped pier located in the center of the intermittent river bed (*fig. 13a*). The rectangular piers are con-

Fig. 12. Urban route of the aqueduct (photo author).

structed of *opus incertum* with rubble cores and incorporated stepped buttresses in both the up and down stream directions. Seven courses of cut ashlar blocks surround the rubble core of the oval shaped pier at the lower level. *Opus incertum* was used to finish the upper section of this pier. The use of buttresses and the curved ashlar block facing reflects the increased concerns over flash flooding. There are few remains of the bridge on the north east side however three spans are intact on the west end of the bridge. Here, the inside of the piers and the intrados arch are faced with ashlar block in a Type B staggered, stretcher bond fashion. ¨ bove the intrados arch is another ring course of small ashlar block inset against the rubble core and topped by a concentric ring of radially laid field stone also inset against the rubble core. ¨ s with the other bridges, the haunches are constructed of *opus incertum* over a rubble core.

The *Kuru Dere B aqueduct bridge* crosses the valley a little farther to the south of bridge ¨ . It too is about half the width of the previous bridges found to the east of Eliaussa. It is constructed of *opus incertum* of rough cut ashlar stone over a rubble core (*fig. 13b*). The channel specus narrowed to around 22-25 cm wide by approximately 25 cm high and the channel walls were only about 20 cm thick. Once again, near the east side of the Kuru Dere B bridge, the ancient aqueduct channel is used as an easy utility corridor for an irrigation pipe which supplies a modern drip irrigation system used for cultivation. Much of this aqueduct bridge is in ruins as it crosses the valley floor. On the other side of the dry river bed, the water channel west of the bridge continued up the hill towards Korykos over a high, solid wall constructed of small rough cut ashlar blocks with a rubble core. Only a small rectangular opening in the west wall provided a north-south pedestrian access. Other aqueducts found in southern Turkey have used small arched arcades in similar situations instead of a solid wall so there is an interesting question as to why the ancient builders chose this particular method of construction.

Fig. 13a. Kuru Dere A aqueduct bridge (photo author).

Fig. 13b. Kuru Dere B aqueduct bridge (photo author).

Fig. 14. Modern pipeline below ancient channel (photo author).

Fig. 15. Ancient sluice gate - Modern water tap (photo author).

Problems the ¨ ncient Builders H¨ d in Common with Tod¨ y's Modern W¨ ter System

Now that the route of the ancient aqueduct has been traced and it has been observed how modern pipelines and water channels follow the general route that the ancient surveyors laid out in many areas as well as how the ancient specus of the empty channel is used as an easy utility corridor for modern pipelines, it would be useful to look at what common problems are shared by both the Roman builders as well as the modern engineers.

It is well documented that ancient aqueducts required continuous Repairs. In figure 14, the modern pipeline has a serious high pressure leak just below the immediate location of the ancient aqueduct channel, the remains of which also showed signs of leakage and repairs in antiquity. This is in an area of the Lamas Valley where the canyon gorge begins to change direction to the southeast toward the coastline and where gradient/water velocity becomes a major factor. ¨ s previously mentioned, Dr. Uyan has written extensively about the hydraulic problems of the Lamas valley that are clearly evident by these modern and ancient leaks. Sinter build up on the outside of the Tirtar bridge is also a visible indicator of ancient leaks along the Elaiussa Sebaste portion of the aqueduct in antiquity just as several other small leaks are evident along the course of the modern pipelines. Problems with pressure and flow are common both today and yesterday.

Fig. 16. Modern use of ancient cistern (photo author).

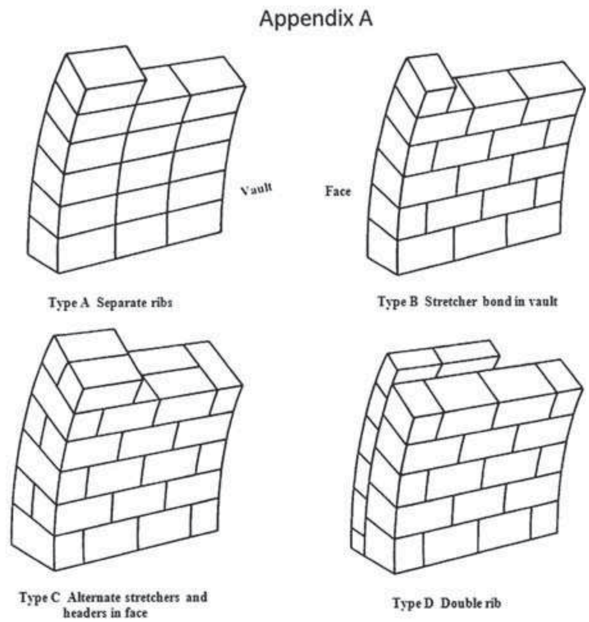
There are several common engineering technologies shared by both ancient and modern engineers that can be observed by looking at the nearby Olba ¨ queduct which also took water further upstream on the Lamas River.

¨ n example of an ancient water tap is found just to the west end of the Olba aqueduct bridge. The water offtake is in the form of a sluice gate cut into a section of the aqueduct channel which provided water to a nearby ancient work center. Today, modern water taps are also visible along many parts of the modern pipelines as illustrated in the inset circle of figure 15. Modern sources have also documented problems with illegal water taps on modern pipelines in the Lamas Valley, something that was also common in the ancient world.

¨ s with many ancient fountains, the Nyphaeum at Olba stored water in a large cistern located under the second platform of the fountain for public use.[10] Modern residents living in a house adjacent to the Nymphaeum today still depend upon the ancient cistern, even if it is now only supplied by rain water and not an aqueduct. The author had the opportunity to photograph the resident in (*fig. 16*) after lowering a tin bucket into the ancient cistern to take water for domestic use. Reuse of ancient cisterns for agricultural purposes is also very common throughout the greater Eliaussa - Olba hinterland. In situations where the capacity of the cistern is insufficient, it is very common to find new open air cisterns constructed with plastic liners very near or even adjacent to the ancient cisterns.

Discussion

The ancient roman surveyors had a difficult task to route the Elaiussa Sebaste aqueduct a distance of approximately 26 kms over very rough terrain while maintaining an average drop of 2.8 meters per km. Their work has benefited modern engineers who still use the ancient channel as a utility corridor. Pipelines are found in the specus of the empty water channel and, in areas where the channel specus no longer exists, the aqueduct foundation can sometimes be seen in use as a support substructure for modern pipes supplying both residential and agricultural purposes. Today, modern builders experience many of the same problems that the ancient Romans did with water line leaks and people today still use ancient cisterns for daily residential water use, as well as for intensive agricultural production. The aqueduct of Eliaussa Sebaste truly has channels for today and yesterday.



Appendix A. Coursing of Roman arch ribs: A: separate ribs, B: stretcher bond in vault, C: alternate stretchers and headers in face, D: double rib (courtesy Colin O'Connor, Roman bridges, 1993, 172).

Notes

* This paper and the Lamas River study has benefited from discussions with Ũ. Öziş and Y. ¨ risoy however the ideas expressed in this article and any errors are the authors. The author also appreciates the very patient help provided by Yalçin Özdemir who was instrumental in helping contact these scholars. The author is indebted to L. Lancaster for her review and suggestions concerning arch construction and vaulting techniques as well as Colin O'Connor for giving me permission to use his arch illustrations but again any errors are the

authors. I am also grateful for ¨ nnalisa Falcone's information about the urban water system of Elaiussa Sebaste, Prof. Schneider's kindness in showing me the excavations on previous visits and Mehmet Bildirici's information on Olba's modern water uses. Special thanks is also due Kurt Drilling who enhanced the quality of the photographs in this article and Lance Haynes for his many suggestions.

1 Schneider 2008, 9-20.

2 Bozkurt 2000, viii, 113.

3 Derman 2001, 1-6.

4 Öziş 1996, 368; Personal correspondence with Y. Özdemir.

5 Uyan 2005, 1-173.

6 O' Connor 1993, 172. The type classification set forth in Roman Bridges is used though out the paper to identify the type of coursing employed in arch ribs (see *Appendix A*). ¨ lso see Roman ¨ queducts in Iberia by Leather who uses the same classifications and further breaks down the types.

7 Leather, 2002, 23. The author further subdivides O'Conner's arch classifications into sub-types 1-4.

8 Lancaster 2005, 86-90. See *Concrete vaulted construction in Imperial Rome.* For similar styles of arches construction as applied to arched barrel vaulting.

9 Schneider, E. 2008, 65.* Personal conversations with ¨ . Falcone.

10 Taşkiran 1997, 93; Bildirici 1994, 463-467. Personal conversations about modern water use in the Olba area.

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