Foundation for Science Technology and Civilisation

Review of Muslim Contribution to Civil Engineering:

Dam Construction

Author: Salah Zaimeche BA, MA, PhD
Chief Editor: Professor Salim Al-Hassani
Editor: Professor Talip Alp
Production: Ahmed Salem BSc

Release Date: December 2001
Publication ID: 4021
Print Copy Price: £45.00 UK

FSTC Limited
9 Conyngham Road, Victoria Park, Manchester, M14 5DX, United Kingdom
Web: http://www.fstc.co.uk Email: info@fstc.co.uk

REVIEW OF MUSLIM CONTRIBUTION TO CIVIL ENGINEERING:

DAM CONSTRUCTION

Introduction

In his `History of Dams,' Norman Smith, began his chapter devoted to Muslim dams,[1] by stating that:

> *`Historians of civil engineering have almost totally ignored the Moslem period, and in particular historians of dam building, such as there have been, either make no reference to Moslem work at all or, even worse, claim that during Umayyad and Abbasid times dam building, irrigation and other engineering activities suffered sharp decline and eventual extinction.*
> *Such view is both unjust and untrue.*[2]

Similar point is raised by Pacey, who notes that it is often said that hydraulic engineering `made little progress under the Muslim,' and that the latter's achievements hardly evolved beyond the Greek or Roman's. Pacey corrects this view, pointing out that the Islamic civilisation adapted ancient techniques `to serve the needs of a new age,' and that the Muslims extended the application of mechanical and hydraulic technology enormously.[3] To explain the reasons behind the belittling Muslim achievements as observed by Smith, Pacey and others[4] is a mammoth a task which requires people versed in political, religious, and historical matters.

Dams and Construction Techniques

The Muslims built many dams in a rich variety of structures and forms. The majority of the earliest Muslim dams were completed in Arabia itself; and full information on their height, length, and ratios between height and length is given by Schnitter. He also specifies that with the exception of the Qusaybah dam near Medina, a 30 m high-205 m long structure, which was slightly curved in plan, the alignment of all others were straight.[5] About half such dams were provided with a flood overflow at one end, and often with a downstream training wall to guide the spilled water to a safe distance from the dam's foot. Schnitter also observes that about a third of such very early dams (7^{th}-8^{th} century) are still intact.[6] In Iraq, in the vicinity of Baghdad, a considerable number of dams were built during the Abbasid Khalifate.[7] Most such dams are on the Tigris, but a few are on water diversions, further illustration of high engineering skills. In Iran can be found the Kebar dam, dating from the 13^{th} century, the oldest arched dam known to have survived.[8] The dam has a core of rubble masonry set in mortar, the mortar made from lime crushed with the ash of a local desert plant, the addition of ash making the lime hydraulic. This resulted in a strong, hard and impervious mortar, ideal for dams, the very reason for such dam's long life, and the absence of cracks in it. Much earlier than this dam, in today's Afghanistan, were three dams completed by King Mahmoud of Ghaznah (998-1030) near his capital city. One named after him, was located 100 km SW of Kabul, and was 32m high, and 220m long.[9]

Dam construction in Muslim Spain was prolific. In the city of Cordoba, on the river Guadalquivir, can be found what is probably the oldest surviving Islamic dam in the country.[10] According to the twelfth- century geographer al-Idrisi it was built of Qibtiyya stone and incorporated marble pillars.[11] The dam follows a zig-zag course across the river, a shape which indicates that the builders were aiming at a long crest in order

to increase its overflow capacity. Remains of the dam can still be seen today, a few feet above the river bed, although in its prime, it was probably about seven or eight feet above high- water level and eight feet thick.[12]

Techniques used by Muslim masons and engineers reached great heights of ingenuity. On the river Turia, still in Spain, as an instance, modern measurements have shown that the eight canals have between them a total capacity slightly less than that of the river, thus raising the possibility that the Muslims were able to gauge a river and then design their dams and canals to match.[13] Smith elaborates on such skills.[14] Muslim engineers used sophisticated land surveying methods to locate their dams in the most suitable sites, and also to lay out very complex canal systems. For such, they used astrolabes and also trigonometric calculations.[15] Around Baghdad water was diverted into the Nahwran Canal which supplied water for irrigation, whilst improvements were made to existing, old systems.[16] Dams were built of carefully cut stone blocks, joined together by iron dowels, whilst the holes in which the dowels fitted were filled by pouring in molten lead.[17] An impressive structure of masonry is Hill's impression of the dam at Marib in Yemen, with its carefully cut and fitted blocks using lead dowels in their joints.[18] It was also fourteen metres high and 600 metres long, with elaborate waterworks including sluices, spillways, a settling tank and distribution tank. So strong a structure, it survived for about ten centuries until lack of financial and technical means made it impossible to maintain.[19] Back in Spain, according to Scott, the masonry of the reservoirs was of the finest description, and the cement used was harder than stone itself.[20] Contingencies were provided for in such manner that no overflow occurred, and no damage resulted even during the worst flooding. Evidence of Muslim engineering `genius' is the fact that these dams needed hardly any repair in a thousand years.[21] The eight dams on the Turia River at first sight seem to have an exaggerated amount of weight placed on their foundations, the masonry of each dam going some fifteen feet into the river bed, and further support provided by the addition of rows of wooden piles. Such solid foundations were justified by the river's erratic behaviour, which in times of flooding reaches a flow that is a hundred time greater than normal, the structure having to resist the battering of water, stones, rocks and trees.[22] These dams, now over ten century old, still continue to meet the irrigation needs of Valencia, requiring no addition to the system.[23] On the River Segura, the Muslims built a dam in order to irrigate vast lands in the Murcia region.[24] Because of the nature of the terrain, not just the location, but the design and construction had to be absolutely perfect, too. The height of the dam was only 25 feet, yet its base thickness was 150 and l25 feet, which may seem excessive. Such thickness was necessary to meet the softness and weakness of the river's bed to prevent it from sliding along. The water flowing over the crest initially fell vertically through a height of 13-17 feet on to a level platform, running the length of the dam. This served to dissipate the energy of the water spilling over the crest. The over-flow then ran to the foot of the dam over flat or gently sloping sections of the face. In this way the whole dam acted as a spillway and the energy gained by the water in falling 25 feet was dissipated en route. Thus the risk of undermining the downstream foundations was greatly reduced. Like with other dams, rubble masonry and mortar were used for the interior, and the whole was finished with large masonry blocks.[25]

Reservoirs

By far, the most original Muslim reservoirs are to be found in the region of Qayrawan in Tunisia. A lengthy (about 270 pages) account of such structures is offered by the French Solignac.[26] These reservoirs, possibly for their high aesthetics, and like many other Islamic achievements,[27] were attributed, despite all evidence,[28] to both Phoenicians[29] and Romans.[30] Such erroneous views were adopted by a number of

scholars until modern archaeological excavations and advanced studies proved the Islamic origin of such structures. These reservoirs have two basins, one used for decantation, one as a reserve, and at times a third one for drawing water out of it. Other than their impressive numbers, over two hundred and fifty in the region, such reservoirs also offer a great attraction in their form and structure.

Water Management

Water management in all its intricacies, from Andalusia to Afghanistan, Bolens reminds, was the basis of agriculture, and source of all life. All the *Kitab al-Filahat* (books of agriculture), whatever their origin, Maghribian, Andalusian; Egyptian, Iraqi; Persian or Yemenite, insist, and meticulously, on the deployment of equipment and on the control of water.[31] The authorities of the time played a crucial role in that, too. In Iraq, as a rule, hydraulic tasks of a vast nature were left to the state, while the local population focussed its efforts on lesser ones.[32] In Egypt, a more elaborate picture comes out.[33] There, indeed, the management of The Nile waters was most crucial to every single aspect of life, and dams responded to such necessity. Both al-Nuwayri[34] and al-Makrizi[35] stressed the role of maintenance of dams and waterways of the Nile for maximum benefits. It was the responsibility for both sultans and holders of large holdings, under both Ayyubids and Mamelouks, to dig and clean canals and maintain dams. As in Iraq the sultan took over the larger structures, and the people the lesser ones. Most distinguished Amirs and officials were also made chief supervisors of such works.[36] Under the Mamluks there was even an officer for the inspection of dams for each province of Egypt: the *Kashif al-Djusur*.[37]

Water Storage

Dams are used to store water, and this has major implications on economic and social life. Smith observes that `not only do dams represent some of the most impressive achievements of engineers over the centuries, but their vital role in supplying water to towns and cities, irrigating dry lands, providing a source of power and controlling floods is more than sufficient to rank dam building amongst the most essential aspects of man's attempt to harness, control and improve his environment.[38] Effective storage and use of water for irrigation, for instance, can have dramatic repercussions, in cheapening the process and bringing into use lands that were hitherto impossible or uneconomic to irrigate.[39] Both Spain and Sicily offer good illustrations of that. Water is also stored for the aim of providing power for milling. In Khuzistan, at the Pul-I-Bulaiti dam on the Ab-i-Gargar, the mills were installed in tunnels cut through the rock at each side of the channel, constituting one of the earliest examples of hydro-power dams, and not the only one in the Muslim world.[40] Another example is the bridge-dam at Dizful, which was used to provide power to operate a noria that was fifty cubits in diameter, which supplied all the houses of the town.[41] Many such hydraulic works can still be seen today.[42]

Transfer of Hydraulic Technology to Europe

The Islamic mastery of hydraulic technology is far more advanced than acknowledged by some of the sources many are too keen to follow, and which hence distorts the exact role of Muslim engineering skills. Indeed, to the likes of Gimpel[43] and White,[44] the Muslims hardly made any contributions in such a field. Reality, however, is far the opposite. First and foremost, the hydraulic works of the Ancients were found by the Muslims in a terrible state of decay and ruin,[45] and they did not just repair them, but also added considerable skills of their own. To Spain, for instance, the Muslims brought irrigation techniques which not

only laid the foundations for the prosperity of the country, but also with nothing as elaborate and as efficient seen before in Europe.[46] After the country was retaken by Christian forces, the Muslims, masters of great skills then, were allowed to retain their functions and serve the new crown. Alongside builders, paper and textile makers, manufacturers of iron and experts of all sorts, the Spaniards also retained and used Muslim irrigation works, their attendant rules and even regulations.[47] And as soon as the Muslims, who refusing to be baptized as Christians were expelled, or massacred, economic ruin, and famine always followed.[48] And Spain never recovered its former prosperity and levels of advancement once the Muslims had been eliminated from its land. Hill also notes that the introduction of desilting sluices, the arch dam, and hydropower made their first appearances in the Islamic world, observing that it is `difficult to see how these can be other than Muslim inventions.'[49] Further illustration of Islamic impact in the field is not just obvious through the works of Hill, Pacey, Smith and others, it is also visible via the works of Muslim engineers themselves as can still be observed through the remains of old age storage structures all over the Islamic land. Furthermore, White's, Gimpel's and their followers' argument lacks historical backing, for the major changes that took place in Europe, and not just in terms of hydraulic technology, but all others,[50] did, and without one single exception, at the time the Europeans came into contact with the flourishing Islamic civilisation (twelfth-thirteenth centuries), and not the centuries before. Also, the fact that Western technology in nearly every respect is identical to the Islamic one offers further evidence of such impact.

The Destruction of Muslim Dams

Like with much else regarding Islamic civilization, once the transfer was accomplished, destruction followed. Muslim dams did not escape in their vast majority the onslaught against Islam. In 1220, the armies of Jenghis Khan devastated the whole eastern parts of the Muslim land. The destruction of al-Jurjaniyah dam south of the Aral Sea diverted the River Oxus from its course and deprived the Aral Sea of water, causing it to nearly dry out centuries later.[51] A hundred and sixty three years later, in 1383, it was Timur's hordes, which this time completed the work of their predecessors. The Tartars laid the land waste, Zaranj the capital of the province of Seistan, suffering terrible fate; its dams and all its irrigation works completely laid waste. A similar fate befell the Band-I-Rustam, and the region of Bust.[52] Today, hardly anything survives in those lands once the seats of great civil engineering accomplishments.

References:

[1] N. Smith: *A History of Dams,* The Chaucer Press, London,1971.
[2] Ibid.; p. 75.
[3] A.Pacey: *Technology in World Civilization, a Thousand year History*, The MIT Press, Cambridge, 1990, at p.8.
[4]See, for instance,
-E.J. Holmyard: Chemistry in Islam, in *Toward Modern Science*, Vol 1, R. Palter edition, The Noonday press, New York, 1961; pp 160-70.
-J.H. Harvey: the origins of Gothic Architecture, *Antiquaries Journal*, 48, pp 87-99.
And anyone taking the bother to read any of the many books or articles devoted to Islamic science that are still accessible, will find support for the opinion of neglect and cover up of the Muslim contribution to world civilization.

[5] N.J. Schnitter: *A History of dams*; A.A. Balkema, Rotterdam, 1994; pp-81-2.
[6] Ibid, p. 82.
[7] N.Smith: A History of Dams, op cit, p.78.
[8] D.R. Hill: *Islamic science and engineering*, Edimburgh University Press, 1993, p. 168.
[9] N.Schintter: A History, op cit, pp 88-9.
[10] N.Smith: A History, op cit, p.90.
[11] In D.R. Hill: Islamic Science, op cit, op cit, p.161.
[12] Ibid.
[13] Ibid, p.165.
[14] N.Smith: a History, op cit, p. 88.
[15] See forthcoming chapter on al-Battani.
[16] A. Pacey, Technology, op cit, p.9.
[17] Ibid, pp.9-10.
[18] D.Hill: Islamic Science, op cit, at p. 159.
[19] Ibid.
[20] S.P. Scott, *History of the Moorish Empire in Europe*; J.B. Lippincott Company, London and Philadelphia, 3 Vols, Vol 3, 1904; at pp. 601-2.
[21] Ibid, p. 602.
[22] N.Smith: A history, op cit, p. 93.
[23] Ibid.
[24] N. Smith: A History, op cit, pp. 94-7; D. Hill: Islamic science, op cit, pp. 166-7.
[25] Ibid.
[26] A. Solignac: Recherches sur les installations hydrauliques de kairaouan et des Steppes Tunisiennes du VII au Xiem siecle, in *Annales de l'Institut des Etudes Orientales*, Algiers, X (1952); 5-273 .
[27] A list that includes Arabic numerals, the invention of the pendulum, the use of the compass in navigation, the vaulted arch in construction, blood circulation, and so on and so forth, all attributed to various sources other than Islam despite all evidence in favour of the Muslims. On the other hand, acts such as the burning of the famed Library of Alexandria were attributed for centuries to the Muslims despite the flimsy nature of evidence. The library was proven to have been burnt centuries before the Muslims entered Egypt(See E.Gibbon, *The decline and Fall of the Roman Empire*, for instance.) Undaunted, some sources still ignore such evidence and keep blaming the Muslims.
[28] M.Shaw: *Voyages de Shaw MD dans plusieurs provinces de la Barbarie et du Levant;* 2 Vols, La haye, 1743; Vol II; pp 257-9; and E. Pelissier: *Description de la Regence de Tunis; Exploration scientifique de l'Algerie pendant les annees 1840-41-42;* Paris, 1853, pp 279-280.
[29]A.Daux: Recherches sur l'originalite et l'emplacement des emporia Pheniciennes dans le Zeugis et le Byzacium, Paris, 1849.
[30]H.Saladdin: Enquetes sur les installations hydrauliques romaines en Tunisie, published by Direction des Antiquites et Beaux Arts, et La regence de Tunisie, Tunis, 1890 a 1912.
R.Thouvenot: Les traveaux hydrauliques des Romains en Afrique du Nord in: *Realites marocaines, Hydraulique, Electricite*, Casablanca, 1951.
[31] Lucie Bolens: Irrigation: in *Encyclopedia of the history of Science, technology, and Medicine in Non Western Cultures.* Editor: Helaine Selin; Kluwer Academic Publishers. Dordrecht/Boston/London, 1997. pp 450-2; at p. 451.
[32] C. Cahen: Irrigation in Iraq; *Encyclopaedia of Islam*, second edition, Vol V, Leiden, Brill, pp.864-5.

[33] H.Rabie: pre-20th century irrigation in Egypt, in *Enbcyclopaedia of Islam*, Vol V, pp 862-4;
[34] Al-Nuwayri: *Nihayat al-Arab*, Cairo, 1923, vol I, p 265.
[35] Al-Makrizi: *Khitat*, Cairo, 1853-4 edt; vol I, p.61.
[36] Encyclopaedia, op cit, p 862.
[37] Ibid, p. 863.
[38] N. Smith: A History, Op cit, preface, p.i.
[39] A.M. Watson: *Agricultural innovation in the early Islamic world,* Cambridge University Press; 1983. p. 104.
[40] N.Smith: A History, op cit, p. 81.
[41] Le Strange: *The Lands of the Eastern Caliphate*, London, 1905; p. 239.
[42] D.R. Hill: Islamic, op cit, p. 160.
[43] Jean Gimpel: *The Medieval machine*, Pimlico, London, 1976.
[44] Lynn White Jr: *Medieval technology and social Change*, Oxford, 1964.
When C. Singer, assisted by Hall and Holmyard completed the edition of the large `History of Technology,' in five volumes, in 1958, the response from Lynn White was vitriolic towards the epilogue written by Singer `East and West in Retrospect.' White used first Speculum (vol 33, 1958, pp 130-5,) and, above all Technology and Culture (Vol 1, 1958, at pp 340-1), a quarterly set up soon after Singer's book, and with him (White) taking one of the leading positions in that journal, to attack Singer's above quoted chapter. Singer is not the first recipient of such attacks, though. Any single book or journal, including the famed ISIS (founded by George Sarton,) that is deemed favourable to Islamic science and technology suffers the same onslaught.
[45] A.M. Watson: Agricultural innovation, op cit, p. 104.
[46] D.R. Hill: Islamic science, op cit, at p. 161.
[47] N.Smith, A history, op cit, p .103.
[48] On the expulsion and extermination of the Muslims in Spain and Portugal, see:
-Jean Read: *The Moors in Spain and Portugal*; Faber and Faber, London, 1974.
-Charles. H. Lea: *A History of the Inquisition of Spain*, 4 vols; The Mac Millan Company, New York, 1907. See volume three, pp 317-409.
-S.P. Scott: A history of the Moorish, op cit, vol III.
[49] D.R. Hill: Islamic science, op cit, pp 168-9.
[50] Including paper making, new architectural techniques, university teaching, the construction of hospitals, windmills, the use of the compass etc..
[51] N. Smith, a History, op cit, p 86.
[52] Ibid.

Bibliography:

-Lucie Bolens: Irrigation: in *Encyclopedia of the history of Science, technology, and Medicine in Non Western Cultures.* Editor: Helaine Selin; Kluwer Academic Publishers. Dordrecht/Boston/London, 1997. pp 450-2.
-C. Cahen: Irrigation in Iraq; *Encyclopaedia of Islam*, second edition, Vol V, Leiden, Brill, pp.864-5.
-A.Daux: *Recherches sur l'originalite et l'emplacement des emporia Pheniciennes dans le Zeugis et le Byzacium*, Paris, 1849.
-E.Gibbon, *The decline and Fall of the Roman Empire*.
-J. Gimpel: *The Medieval machine*, Pimlico, London, 1976.

-J.H. Harvey: the origins of Gothic Architecture, *Antiquaries Journal*, 48, pp 87-99.
-D.R. Hill: *Islamic science and engineering*, Edimburgh University Press, 1993.
-E.J. Holmyard: Chemistry in Islam, in *Toward Modern Science*, Vol 1, R. Palter edition, The Noonday press, New York, 1961; pp 160-70.
-Charles. H. Lea: *A History of the Inquisition of Spain*, 4 vols; The Mac Millan Company, New York, 1907.
-Le Strange: *The Lands of the Eastern Caliphate*, London, 1905.
-Al-Makrizi: *Khitat*, Cairo, 1853-4 edt; vol I.
-Al-Nuwayri: *Nihayat al-Arab*, Cairo, 1923, vol I.
-A.Pacey: *Technology in World Civilization, a Thousand year History*, The MIT Press, Cambridge, 1990.
-E. Pelissier: *Description de la Regence de Tunis; Exploration scientifique de l'Algerie pendant les annees 1840-41-42;* Paris, 1853.
-H.Rabie: pre-20th century irrigation in Egypt, in *Enbcyclopaedia of Islam*, Vol V, pp 862-4;
-J. Read: The Moors in Spain and Portugal; Faber and Faber, London, 1974.
-H.Saladdin: Enquetes sur les installations hydrauliques romaines en Tunisie, published by Direction des Antiquites et Beaux Arts, et La regence de Tunisie, Tunis, 1890 a 1912.
-M.Shaw: Voyages *de Shaw MD dans plusieurs provinces de la Barbarie et du Levant;* 2 Vols, La haye, 1743; Vol II.
-N.J. Schnitter: *A History of dams*; A.A. Balkema, Rotterdam, 1994.
-S.P. Scott, *History of the Moorish Empire in Europe*; J.B. Lippincott Company, London and Philadelphia, 3 Vols, Vol 3, 1904.
-N. Smith: *A History of Dams,* The Chaucer Press, London,1971.
-A.Solignac: Recherches sur les installations hydrauliques de kairaouan et des Steppes Tunisiennes du VII au Xiem siecle, in Annales de l'Institut des Etudes Orientales, Algiers, X (1952); 5-273.
-R.Thouvenot: Les traveaux hydrauliques des Romains en Afrique du Nord in: *Realites marocaines, Hydraulique, Electricite*, Casablanca, 1951.
-A.M. Watson: *Agricultural innovation in the early Islamic world,* Cambridge University Press; 1983.
-Lynn White Jr: *Medieval technology and social Change*, Oxford, 1964.