UNDERGROUND MILLS IN IRAN

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This contribution forms part of the study of the question : how much water to drive the mill ? Most of the examples, at first hand or drawn from the literature on the subject so far as the Middle East is concerned, are horizontal mills in Iran or Afghanistan.

Few traditional mills work here now, except in villages remote from main roads, unconnected to the electricity grid and too poor to afford the fuel (Iran's major product, after all) that would power simple mechanical mills. Once, however, water had to be husbande and organised to produce the flour needed by a nation of bre d-eaters like the Persians. How much science, in their bones rather than in any books, went into the arrangement of a horizontal mill in a Persian village or town ? And, viewed from an almost archaeological standpoint in 1983, how efficiently did they make use of their water supply ? Figures are hard to come by and very few mills have been recorded in Iran. Now it is almost too late: there is no enthusiastic and confident small watermilling fraternity in Iran as ther is in Britain and other parts of Western Europe.

My currently unresolved questions are to do with the establishment of a head of water and the power provided by a traditional penstock, especially when these are required by a genuinely subterranean mill. Apart from the authorities quoted, I have yet to include and consider properly the Cretan findings of N G Calvert. A useful study of the underground water system of Iran appeared in last year's journal of the British Institute of Persian Studies and has been briefly referred to here. Additional fieldwork in Iran and Afghanistan has been well-nigh impossible for about five years now, owing to the political situation in both countries, so one theorises on very incomplete and inadequate evidence !

A century ag the British consul in N. E. Iran recorded during his travels in west Afghanistan, 'At Sadat I found a curious watermill. The water channel, which was on the surface, dropped some fifteen feet down a brick well and turned the mill in a hole in the ground at the bottom, the water running on underground in a fresh channel until it came to the surface again lower down" (Yate, C. E; Khorasan and Sistan, Edinburgh, 1900).

An interesting, though disused example of just such a horizontal mill was seen by me in 1977 near the village of Salameh in east Iran. This mill had two brick-lined wells at the end of a long leat. One was for wheat, one for barley, I was told. How much thought went into sinking the two, rather than just one ? One clue may be that it was an estate mill, since it is near the big house with its former population of family and servants and their needs as a predominantly bread-eating community.

The water supply, open to evaporation over a surprisingly long distance, came from either a subterranean conduit or a stream below the dam. This lofty stone dam, five or six km further up the valley, represented a good power source, yet unused. Surely it would have been easier to take donkey loads of grain to a mill beside the dam rather than go to the great labour of excavating and shoring up safely this spacious subterranean millhouse ? Spreadeagled on the shallow mud dome, I squinted through the aperture at its centre into the murk below and estimated seven to nine metres to the floor.

A further puzzle is the arrangement of the tailrace. The land was certainly

dropping perceptibly, but the tailrace tunnel must have continued for a long way before before it reached the surface. My failure to carry out more observations must be put down to the heat and the dire effects of the excellent meal the estate steward provided me with in the big house. He was far more interested in horses than disused mills and gave me little information.

At the beginning of the twentieth century, when the village numbered only five hundred inhabitants, the surplus of corn grown locally and exported was remarkable, yet at the same time the dam, capable of irrigating a hundred ploughs of land, was in a ruined state. (Adamec, L; Gazeteer for Meshed and N E. Iran, Graz, 1981). Perhaps the mill was built at that time.

I imagine only one pair of stones worked at any one time, if for no other reason than that the long open leat and complicated arrangements for water distribution would only supply the mill with a limited amount of water. The "sang-i asiab", the amount of water needed to turn a mill (without benefit of a penstock) was reckoned at 280 l/s (Noel, E; R C. A.S. Journal vol 31, 1944, p192). The two penstocks here, comfortably wide enough to climb down and repair, would have held enough water at a good height, but who knows how often the water was in fact below the optimum level for such a penstock? Avitsur recommended 4-8 m (On the History of the Exploitation of Water Power in Eretz-Israel: Tel Aviv, 1960, p viii). As the water supply slackened, the miller should have inserted smaller bore nozzles in the jets if he worked his mill on the pattern described by Hans Wulff, a respected authority on Persian technology in the 1930's and 40's. He gave teutonically detailed figures to link head of water, bore of nozzle, power output, speed of stones and grain throughput in a Siraz mill, though how reliable the figures are and how he measured them remain unknown. The head of 7·6 m remained constant; in the winter and spring a 115 mm diameter nozzle permitted 164 rpm, ca 10 hp (7·5 kw) and ca 150 kg of grain ground per hour, whereas at the drier end of the summer a 76 mm nozzle reduced the power output to 4·5 hp (3·3 kw), speed to 151 rpm, and throughput to ca 70 kg per hour (Traditional Crafts of Persia, M I. T, 1966).

Persian penstocks do not caontain the waterwheels and so are not turbines. What then is the relation between the kinetic energy and pressure when the water head emerges at the base of the penstock to hit the wheel in a jet? Presumably the velocity of the jet is what matters in the creation of power? The velocity is conditioned by the head and the diameter of the nozzle and then exerts its own pressure on the blades of the wheel. In Persian examples these blades are only very roughly and shallowly scooped, if at all, to utilise the weight of the water in addition.

Two final considerations before leaving the mill at Salameh. Firstly, perhaps the running of several pairs of stones simultaneouly in any but a tide mill is and was the exception rather than the general rule. Water supply is only one possible reason for this. I am reminded that the water stored in the millpond at Lode, an English watermill, will only last for about two hours when running the mill at full capacity; it must be run lighter and one pair of stones is dropped out. Secondly, on a big estate where the landowner's word was law experiments with milling might have been carried out, even in Iran. It certainly happened in 19th century Hungary. Water measurement has been got down to a fine art by Persian peasants; they would know how much water to expect in that long leat unless the winter had been very dry and short on snow. They may have sensed that this grand double-welled mill - dreamed up in the landlord's Tehran office rather than a local pragmatic notion - was doomed to become a white elephant before long.

Water above ground is unusual in Iran. It is kept below the surface for as long

possible, to avoid evaporation. It seems that mills were placed partially or even completely within a system of coduits or 'qanat', which tapped natural reserves of water deep below a mountainside, for the sake of agriculture, 15, 25, even 30 km away (see diagram 39, Beazley, E, & Harverson, M; Living with the Desert, Warminster, 1982). Watermills within the system are referred to briefly by Wulff (op.cit, p.282) and by Bonine, M E; in Iran XX 1982, p 148. The average flow in the qanats of Iran has been estimated at 42 l/s (Noel, op.cit. p192). You will recall that the sang-i asiab was 280 l/s. Therefore a sharp fall within a qanat is essential to create sufficient power to turn a mill. To obviate damaging turbulence at this point (if a sudden fall of several metres is incorporated into the qanat) and for some distance down the millrace section of the qanat, hoops of fired clay must have been carefully inserted. This is common practice when tunneling a qanat in unstable soil. Would the water have fallen down a chute, or would the qanat have been greatly enlarged to form a penstock, or would the mill and penstock have been built in a bypass tunnel ? I find the last suggestion most likely. I say 'must have been' and query the method of water supply at the mill because I have yet to come across a mill within a qanat, as opposed to one near the exit, or to one at the start, as at Salameh.

Did this modern geographer invent the system he described 25 years ago ? For what follows sounds more Roman than Persian engineering. "Where the slope of the ground is sufficiently steep, the qanat canal may continue as an elevated aquaduct until it is some ten feet (3 m) abouve the ground level when the water is dropped to operate a grain mill, half underground. The water may then continue, first in a qanat tunnel and again in an aquaduct to operate a second mill. Sometimes there is a series of mills, all underground, where the qanat stream does not appear above the surface at all" (Cressey, G.B; Geographical Rewiew 48, New York 1958, p29). He gives no sites or references. I should be glad to be convinced, but seeing must be believing. At present, in Khomeini's Iran, where much is expected to be taken on faith - Islamic faith - that would be a hazardous undertaking.

There are very few references to definite mills in qanats in travel literature; one seen near Natanz in the 1930's at a depth of 6 m had its stones 'propelled by the force of the stream underneath acting upon a paddle wheel' (Filmer, H; The Pageant of Persia, London 1937, p129). But the tourist did not examine the mill in any greater detail.

The maximum flow quoted for any qanat in the most recent book on the subject is only 226 l/s (Goblot, H; Les Qanats. Une Technique d'Acquisition de l'Eau. Paris 1979, p 42). The author also says that he has come across no mills turned by qanats still working in Iran. Since the usual gradient is 0·5% it would seem that somehow a penstock would have to have been constructed within the qanat. The fall need not have been more than a few metres; Alan Stoyel has recorded a Spanish horizontal wheel, under a 2 m head, driving a sawmill, and measured another fall of only 75 cm. (Spanish Watermills, SPAB Section meetings, November 1978 and 1979). Avitsur estimated that a 2 m head and a 55 cm pair of stones would require a flow of 85 l/s for adequate operation (op cit. p viii); quite within the capacity of a Persian qanat (which was not in his mind at the time). An arubah penstock of the standard 4 - 8 m size would power 100 cm stones and require a flow of only 15 l/s.

It would be interesting to know the flow that fed the Cretan penstock at Zaros visited last year by Frank Gregory; its height was 12 m and its diameter 900 mm. Over a century ago Fairbairn noted that a small diameter penstock needs a greater head to overcome friction, but that it also requires a far lower rate of flow; thus a

900 mm pipe and a 1 900 mm head needed 8·5 l/s, whereas a 1 800 mm pipe and a 970 mm head needed 37 l/s. What happens to the friction factor if an attempt to increase velocity (in Fairbairn's case, 2·1 l/s) the head is raised and the large diameter is retained ?

No Persian peasant building or operating a mill is likely to ask himself precise questions about friction. If the mill has been modelled on others in the neighbourhood he expects it to work with tolerable efficiency and minimum maintainance. That is all he asks for. The water supply, so often from qanats in Iranm except in the mountains, has set bounds to that efficiency. If it fails or decreases, the miller will lessen his expectations and seek other means to eke out a living. God gives man water. Improving on performance by the concious application of hydraulics seems to him a fantasy; more of one that waiting for electricity to arrive or going down to town with one's grain in a jeep to pay for it to be ground by a diesel-powered mill.

What interest me is the manner a limited water supply was still being used 30 to 40 years ago, when other options opened and watermilling began steadily to lose ground and give way without a fight - and scarcely even lamented. Does this sound very much like England a century ago ?

Discussion

Freedman — Do these qanats have to pass through rock ?

Harverson — They do at times, or more often, go round rock. It is mainly through alluvial soil; it's got to be soil through which little water is lost. The water they have tapped must go the whole way down to where it is needed. The loss of water into the surrounding soil even on a very long qanat - say a 30 km one - is reckoned to be not very great.

Plunkett — 30 km on the same gradient ?

Harverson — Yes

Plunkett — It must be very well engineered.

Freedman — It must be a very impervious kind of soil; with most the loss would be enormous. It must be lined with clay, or something of that kind.

Harverson — They normally only line the feeder channels at the head - that is the mountain end - for the first few km.

Freedman — Don't they use masonry at all, where there is any fall they can use slabs of stone.

Harverson — They could use it, but normally there is no need for it, until they get to the exit of the qanat. In the main part of the system there is no masonry at all.

Bryan — Were they able to actually dam the water in the wells so that they operated only part of the day from stored water, and so gain much more power for a short time ?

Harverson — If they were used now, the answer would be yes, for the qanat belongs to the person who has done the work; it is generally a big landowner who wants water for his village, and if he cares to install a mill, and rent it to a miller, then they agree on terms, and there is no problem.

Bryan — Did you say you have seen one ?

Harverson — I have seen where they were, and this puzzled me, for they have this huge drop of nearly 9 m, and to get that water back to the surface they would have had to take it on over a mile it must have been - I never did get to the exit. From where I was standing I couldn't imagine it reaching the surface at all. No one could reach there dry, and I did wonder then whether the whole thing might have been an elaborate white elephant.

Turner — What was the frequency of these mills, as far as you were able to judge, because surely every village would require one?

Harverson — That is very difficult to judge, like your Italian mills; you can almost walk over a watermill in Iran, and not know it is there. They are very often tucked down, and the same colour as the surrounding earth. To answer your question, the village I was staying in when I went up to this place hed windmills. It had 50 windmills and 5 watermills (this was in 1900) and a population of about 10 000. Then there were about 15 000 semi-nomads in the surrounding country, but they also had access to other windmills not very far off.

Bryan — With these watermills, are we talking about a single pair of stones and a waterwheel?

Harverson — Yes, a horizontal waterwheel.

Bryan — And the windmill would also have a single pair of stones? Nothing like the capacity of a European windmill.

Harverson — Yes. The generally-quoted figure for both wind- and watermills is 300 kg a working day. That's an average.