ABSTRACT

In Mediterranean lands, particularly in Syrian valleys, the waterwheel represents a viable and elegant example of a sustainable irrigation system, whose functional aspects are successfully combined with their aesthetic characteristics. Using the power of the river, this waterwheel raises water to irrigate fields which are at a higher level than the level of the water. The system is composed of a vertical wheel and an aqueduct. The base of the wheel is submerged in the river and turns because of the current. Water is carried to the top of the wheel and is poured into the channel on the top of the aqueduct, and is directed to irrigate fields and gardens. The advantages provided by the material, which is easily available in the area, and the morphological characteristics of the land, have allowed the construction of numerous examples of this system of irrigation.

This paper deals with the architectural aspects of the Syrian water-wheels and their relations with the surrounding lands, showing how these devices are visually impressive, present a variety of shape and are of great historical, environmental and iconographical importance, being of accurate and detailed design.
I | General characteristics

Water-wheels in Syria are an ancient type of water architecture which has had a fundamental role, over the centuries, for irrigation and supplying water to houses and public constructions.

Syrian water-wheels successfully combine the functional with the aesthetic, are sophisticated forms of construction, have historical, practical, environmental and iconographical importance. They present a variety of shape which are the results of an accurate and detailed design.

In general terms the system is composed of two main parts. The first includes one or more wheels, made of wood; the second is the aqueduct, made of masonry. The installation always includes a vertical wheel which is placed beside the aqueduct, on the bank of a stream or partially inserted underground and, depending on the type, it can also include one or more horizontal wheels. The vertical wheel turns because of the river current or the power of animals or men. Water is raised by the wheel and poured into the channel along the top of the aqueduct. From there it goes into the cistern or irrigation channels.

Water-wheels are primarily divided into three main types: machines moved by the power of animals, i.e. saqiya and noria, men, i.e. treadwheel, or by water itself, i.e. hydraulic noria.

The large diffusion that these installations have had over time in a broad geographical sense, until the advent of new oil and electricity-based technologies, is due to their numerous advantages. These advantages include the simple and efficient mechanism of these structures, the easy assembly and maintenance of the wheels, their successful integration into the landscape and the simplicity and economy of their construction. Of the two groups identified in Syria, i.e. water-wheels moved by animals (sāqiya and noria) and those moved by water (hydraulic noria) the latter has played a fundamental role in Syrian cultural tradition.

2 | Water-wheels in Syria

The study of the Syrian type of hydraulic norias on the Orontes has clarified the uniqueness of these devices, also compared with important installations which were in use in other parts of the world like Egypt, Spain, Portugal, Iraq, Morocco, France, Brazil, Mexico, Cambodia, Thailand, China and in East Syria where only a few remains of masonry works of hydraulic norias have been found on the Euphrates and Khabur rivers. In some of these countries – i.e. in South East Asia – they are still in operation. In Syria most installations have been found in the western side of the country, along the Orontes, while on the East side only a few remains of masonry structures of hydraulic norias have been found on the Euphrates and on the Khabur river.

Syrian hydraulic norias are numerous on the Orontes because of the morphological characteristics of the river, i.e. a constant speed of the river, the gradual slope of the ground and the absence of consistent floods, which have had an important role in the diffusion of many installations, and also in determining a unique shape of the wheel which characterizes the devices.

This type raises water using the great power provided by the river. Hydraulic norias are employed where the level of the river is considerably lower than the level of the river’s banks. Consequently they are necessary in order to raise the water to the banks.

The base of the wheel is submerged in the river and turns because of the current. Water is carried to the top of the wheel, through box containers placed on the periphery of the rim, and is poured into the channel on the top of the aqueduct, and goes to irrigate the fields. Where the wheel is submerged into the river, the power of water presses on the paddles placed on the periphery of the wheel causing the rotation of the wheel itself and the filling of the compartments.

A stone structure (the so-called “triangle”), because it is triangular in shape, supports one of the ends of the wheel-axle and has steps on both sides to allow access to the navel of the wheel for maintenance. The other end of the axle is placed on the sill of the aperture of the so-called “tower”, that is the fronton of the aqueduct. At the bottom, the wheel rotates between the triangle and the façade of the tower.

The channel which conveys water to the wheel, because of its particular profile and small width, increases the flow of water under the wheel and can be closed when it is necessary to stop the rotation (for example for maintenance).

The rotation velocity of the wheel increases with the velocity of the flowing water. Thus, the most appropriate locations to install the water-wheel are in places where the water stream is narrower, causing the water velocity to reach the highest safe value.

The size of the wheel is variable, depending on the quantity of water to raise. The diameter can range between a few metres and more than 20 metres. The biggest water-wheels raised 150 to 180 litres per second. The average was 45 litres per second which allowed an irrigation of 25 hectares.

To move the wheel continuously, it’s necessary that the river flows at a constant speed. For this, secondary masonry structures are built. A dam, bars the river...
to maintain an initial sufficient level of water and to increase the speed of water in the main channel. One or more derivation channels regulate the level of the water during periods of plenty or scarcity. The barrages cross the derivation channels allowing the flow to be regulated.

2. Axonometry of a hydraulic noria on the Orontes river

On the basis of the evidence available and of the sources analyzed, a theory of the origin of the Syrian hydraulic noria that has been put forward is that it first appeared during the Roman time between 60/50 B.C. and the early 3rd century A.D. With the advent of Islamic technology, the design of the wheels may have changed, while aqueduct and tower would have preserved the original shape.

The new design of the wheel is the ideal to deal with the great power of the river, because the shape is strong due to the position of the spokes which start from 4 centres equidistant from each other and from the circumference. This shape allows a better distribution of the internal forces involved. This shape is not only due to the necessity to obtain a strong structure of the wheel, but it also derives from a geometric construction consisting of an intersection of star-shaped figures. This new shape, which probably dates back to a period between the 9th and the 12th centuries, has been transmitted until now. The uniqueness of the shape of the Orontes wheel is in its “polycentric” radiality. In a broader geographical sense it has been possible to identify designs which show different regional variations and are the results of precise geometric constructions. It has been shown that the design of the wheels can be characterized by “radial” or “polygonal” shapes, or by a combination of these. The identification of these shapes has underlined the uniqueness of the “polycentric” radiality of the Orontes wheels, obtained combining the best hydraulic and mechanical efficiency with a detailed geometric construction, in order to deal with the strong current of the river.

It has also been noted that the type of wheel design is linked to the strength of the river current. Polygonal shapes, with a reduced number of radial spokes and a predominance of oblique secondary beams, of the type used on the Guadalquivir river in Spain and in Maghrib, deal with weaker river currents, unlike wheels with a predominance of radial spokes which are able to support a greater river power, like the East Asian water-wheels. The Orontes types are the strongest. The secondary spokes, starting from 4 centres, create a natural strengthening of the main beams, making the structure more resistant to the forces of inertia and gravity, to hydraulic and transversal thrusts, and preventing major warping.

3 | Architecture and Nature

Up to now the value and importance of Syrian hydraulic norias has been related only to their functional aspects and the advantages provided to the immediately surrounding lands. The analysis of the structures has demonstrated that Syrian hydraulic norias have played a particularly significant role in combining design, efficiency and environment, and were also an authentic expression of an architecture with specific and defined artistic connotations. It is possible to identify a variety of types of hydraulic noria depending on the number and position of towers, aqueducts and wheels. The integration between architecture and nature is an important characteristic of hydraulic norias in Syria. The Orontes valley has been the ideal place for the development and diffusion of numerous hydraulic norias because of the particular characteristics of the river and of the surrounding hills. And – in fact - a close integration of these structures into nature has been shown not only by the layout of the structures, but also by the use of the materials employed to make the structures. The use of local wood and stone, together with the river water, allows a close integration of these installations into the landscape. In fact the ideal wood for building different elements of the wheels is available near the Orontes. Poplar plantations can provide timber up to 15 metres long to make the spokes for the large wheels, and wood which is easy to work to make the small parts. Mulberry is the ideal material for the load-bearing axle of the wheel. The limestone employed for the masonry structures may not at first seem ideal because of its permeability. However, because the water of the Orontes is rich in calcium, it tends to deposit a thin layer on the limestone walls, making them water-proof. So, the chemical characteristics of the river water improve the durability of the masonry. In addition, the lightness of the structure of the wheels often makes them – particularly the wheels far from the city - appear part of the natural landscape.
4 | Renovating Syrian water-wheels

Thanks to the introduction of new technologies based on oil or electricity, modern irrigation systems have replaced the old hydraulic norias. The use of water-wheels declined gradually in Syria. Starting from the late 1950s, modern hydraulic works were carried out in order fully to exploit the area in terms of agriculture by regulating the flow of the Orontes, avoiding the winter floods and guaranteeing the quantity of water necessary for irrigation and the production of electrical energy.

They include the construction of reservoirs created by new dams along the river, which normally fill during the winter and are used for irrigation in the summer, when the dam is opened, and water enters the river. In summer, when the river has been sufficiently filled by the reservoirs, electrical pumps raise and pour water into a network of artificial canals to irrigate the fields.

It is also possible to find modern hydraulic pumps for irrigation placed close to the old hydraulic norias in order better to exploit the quantity of water available in the area. In some cases, the old aqueduct channels are employed for carrying water, raised by the pumps, to the fields.

Although hydraulic norias provide significant environmental and economic advantages, as well as those of safety, it is difficult to develop a basic recipe for renovating hydraulic norias in the Orontes valley. By evaluating the feasibility of renovating hydraulic norias as a sustainable system, as well as an expression of historical and cultural heritage, it has been noted that a re-employment of the hydraulic norias for their original purpose would present considerable difficulties.

In fact the big hydraulic works carried out in the Orontes valley have reduced the level of the river making an eventual rehabilitation of hydraulic norias very difficult. When hydraulic norias stopped working, they were subsequently abandoned for several years and most of them deteriorated considerably and some aqueducts collapsed. Recent constructions have been built on the foundations of collapsed aqueducts obstructing their original course.

Consequently a restoration aimed at re-activating them would mean reconstructing, in many cases, entire aqueducts or demolishing recent constructions abutting on the remains of aqueducts. In addition re-activating hydraulic norias would not solve the increasing need for water, also if they would be supplemental irrigation systems. Rehabilitating hydraulic norias for their original purpose, could also decrease their cultural value as they might be seen as primarily utilitarian.

By contrast, a preliminary proposal that has been put forward has aimed to re-evaluate Syrian water-wheels in terms of historical heritage and ancient tradition, giving a great contribution to the knowledge and studies of water architecture in Syrian lands and increasing the awareness of the historical and cultural value of the sites.

5 | Conclusions

In the light of the study of all Syrian hydraulic norias and their important role played over time, a possible re-evaluation has been considered. By evaluating the feasibility of renovating hydraulic norias as a sustainable system, as well as an expression of historical and cultural heritage, it has been noted that a re-employment of the hydraulic norias for their original purpose would present considerable difficulties, despite the advantages that it could provide. In addition, a re-use could also decrease the cultural value of the structures, as they might be seen as primarily utilitarian.

The preliminary proposal which has been put forward aims to re-evaluate Syrian water-wheels in terms of historical heritage and ancient tradition, as these water-wheels are powerful in their multiple connotations and sustain a particularly significant position in the history and culture of Syria. These structures should be placed firmly within the repertory of historical water typologies as well as within Syria’s architectural heritage.
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