

FUNCTIONING OF GARKAZ EARTH DAM, GORGAN WALL AND ITS CHANNEL AS AN ANCIENT FLOOD DIVERSION PROJECT

FONCTIONNEMENT DU BARRAGE GARKAZ, DE LA PAROI GORGAN ET SON CANAL TEL QU'UN PROJET DE DERIVATION DE CRUE

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ABSTRACT

There are remnants of a huge project which had been constructed 1500 years ago in the north east of Iran. It contains a wall called Gorgan wall, an earth dam called Garkaz dam, a ditch and channels. The related structures of the project belong to 5th century (or, at the very latest, early 6th century) A.D. This date coincides with a long lasting military conflict between the Sasanian Empire and the country on its north. Archeologists believe that the aim of the wall was to protect the north-eastern borders of the Sasanian Empire, which demonstrates the threat posed by its northern neighbors. They also believe that the most important features of the Gorgan wall were its engineering systems, construction methods and its water management in military systems. In this article the hydraulic functions of the dam, channel and ditch are investigated. The results of archeological studies, hydrological data of river and topographical information are used to estimate the flood and capacity of channels. Therefore, this complex was able to divert discharges less than 25 years return period. Also, the ditch worked as consequent reservoirs to save the flood water along the wall to prepare a defending channel. The Garkaz dam, Chae Ghushan channel and ditch were the flood diverting systems which were designed at very old time.

Key words: Gorgan wall, Garkaz dam, ancient structures, flood diversion.

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RESUME ET CONCLUSIONS

On a constaté, dans les photos de satellite de la région Golestan, située au nord-est d'Iran et aussi au sud-est de la mer Caspienne, une ligne rouge qui est les restes d'un grand mur et à cause de ses briques rouge, on l'appelle le serpent rouge. Ce mur est connu aussi aux noms; le mur d'Alexandre, la ligne d'Anoshiravan, la ligne de Firouz et le mur de Gorgan. Le mur commence par la mer Caspienne à Gumishan, continue vers l'est et se termine au nord-est de la ville Kalaléh dans les montagnes Gulidagh. La vraie longueur du mur n'est pas précise, mais de différents chercheurs l'ont évaluée entre 155 et 195 km. Dans les dernières recherches on a déclaré la hauteur du mur, dans les différentes distances, entre 2 et 5 m, avec une largeur de 10 m. Dans la partie ouest, les briques font 37 sur 37 cm et dans la partie est, 40 sur 40 cm avec une épaisseur entre 8 et 11 cm. Dans cette région il y a deux rivières importantes qui s'appellent Atrak et Gorganroud. Sur Gorganroud on a construit une digue poussiéreuse avec une hauteur de 20m de la rivière. La longueur de la crête de la digue était 470 m mais aujourd'hui il reste seulement 300m. La coupe de la largeur de la digue ressemble à un trapèze. Dans les recherches de l'année 2005, on a découvert un fossé et trois canaux au bord du mur. Le fossé, avec une largeur de 30 m et une profondeur variée entre 5 et 7 m, se situe dans la côté nord du mur. Les canaux liaient le fossé à Gorganroud. Près de la digue Garkaz il y a le canal Chae Ghushan avec une largeur de 12 m et une profondeur de 5m, qui transférait l'eau de Gorganroud au fossé. Il y a deux autres canaux ; Agh abad et Sarli Makhtium, qui se situent à 12 km et à 18 km de l'ouest de Chae Ghushan. La pente de la région, en considération de la topographie, est 0.0011. Des recherches archéologiques montrent que le but principal de la construction du mur, de la digue, des canaux et du fossé était le transfert de l'eau de Gorganroud au derrière du mur, remplir le fossé et construire un obstacle devant les ennemis du nord. Mais outre défendre, cet ensemble avait des autres fonctions ;

- la déviation de l'inondation
- la réserve de l'eau
- la distribution de l'eau pour l'agriculture
- la garantie de l'eau potable

La capacité du canal Chae Ghushan est 355 ($m^3 s^{-1}$), qui égalent une inondation avec la période du retour de 50 ans. Alors il y a deux probabilités: ou bien la digue avait un déversoir qui laissait passer l'inondation de plus de 25 ans, ou bien il n'y avait pas de déversoir et dans le deuxième cas la digue était dans une situation dangereuse. La longueur du fossé était 145 km de la digue Garkaz à la mer caspienne. La vitesse et le débit de l'écoulement ont été calculés par les équations de la résistance et les résultats montrent que le fossé, pour une profondeur de l'eau entre 5 et 7 m, a besoin d'un débit 510-932 ($m^3 s^{-1}$) La profondeur de l'eau avec la période du retour de 2 ans c'est 1.73 m. Donc le fossé, comte tenu de la profondeur basse de l'eau, n'avait pas de fonction de défendre, à moins qu'il ait été construit comme un dépôt avec des barrières qui réservaient l'eau dans le fossé et augmentaient la profondeur de l'eau pour défendre et de plus pour garantir l'eau buvable des soldats et des animaux et aussi pour irriguer. Alors en considération de cette analyse hydraulique, on peut dire que cet ensemble de 1500 ans, serait un projet de la déviation et de la réserve de l'inondation pour les buts déjà mentionnés.

Mots clés : *Paroi Gorgan, barrage Garkaz, anciens ouvrages, dérivation de crue.*

(Traduction française telle que fournie par les auteurs)

1. INTRODUCTION

A red line was seen in the old satellite images of Golestan province in the north of Iran and south east of Caspian Sea; this is called the “Red Snake” which was the remainder of a huge wall that was red because of the color of its bricks. It is also known as Eskandar (Alexander) Wall, Anoshiravan Dam, Firouz Dam and also Gorgan Wall.



Fig. 1. Location of the Gorgan wall (localité du Mur Gorgan)

The Golestan province is located between 36°, 24' N and 36°, 38' N Latitude and 53°, 51' E and 53°, 56' E Longitude (Fig. 1), at the south-east corner of the Caspian Sea and it is one of

the most important ancient parts of Iran, attributed to the ancient Hyrcanians era. Because of its long history, Gorgan Plain was pointed by archeologists during the last century (Nokandeh et. al., 2006). They have done some investigations and presented several historical sites such as Qaboos brick tower, Jorjan ancient city, Abadan-Tappe, Gabri-Ghal'e, Dasht-Ghal'e, Qarah-Sheikh Tappe Radkan tower, etc., which point to the geostrategic and significance area in so many years ago.

There are two main rivers in this region, Atrak River in the north border and Gorganroud River, both of them flow from east to west and pour into Caspian Sea (Fig. 2).

Jacques De Morgan was the first person who has done some explorations in this region in 1886, and T. Arne, had surveyed some parts of the wall about 60 years later. Upon Arne's scheme, in 1950 an American pilot, Erik Smith, took aerial photograph (Nokandeh, 2006). Although Arne's archeological survey can be presumed as the basis of the next explorations. The first serious study on the site occurred in 1971 by an archaeological team led by Dr. Kiani (Kiani, 1982).

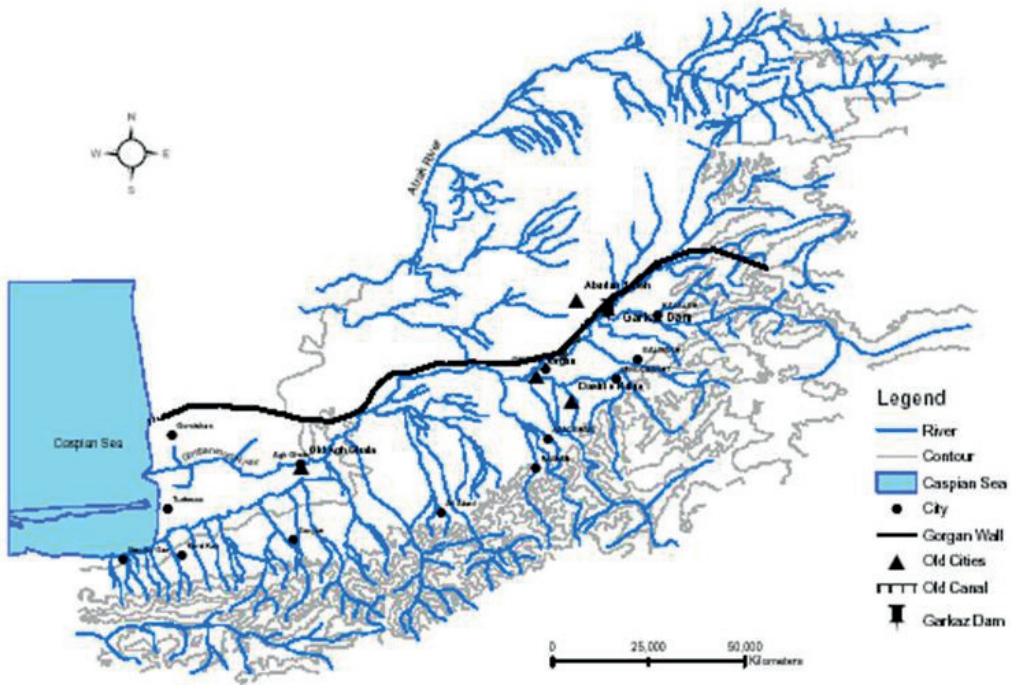


Fig. 2. The wall area , and surface water resources, old and new settlements (la région du Mur, les sources de l'eau de la surface et les régions habitées nouvelles et anciennes)

Some people believe that it was built under the Macedonian king , Alexander the great, who reached to this region in 330 BC, but died seven years later, indeed the Wall is also known as 'Alexander's Barrier'. Others expressed that it was built in the 6th century AD under the great Persian king "the first Khusrau" (AD 531-579). Owing to M.Y. Kiani's 1970s fieldwork and many researchers thereafter, it has favored a 2nd or 1st century BC construction. The second thorough analysis of the structure was made by an archaeological survey team in

1990s. This was a part of the activities related to the construction of Golestan Dam. During their fieldwork, remaining part of an ancient dam and channels and water conveyance systems had been found and thenceforth it became one of the most important projects of cultural heritage organization of Iran led by J. Nokandeh and H. Omrani Rekavandi. The most recent studies occurred in early 2008 by an international archaeological team composed of specialists from Iran and England (the Universities of Edinburgh and Durham) and it is still continued. According to Dr. Jean-Luc Schwenninger and Dr. Morteza Fattahi works and the results of OSL⁵ samples which were taken in October 2005, they demonstrated conclusively that the wall had been built in the 5th or, 6th century AD (Omrani, et. al., 2008).

The Wall runs from the Caspian Sea in Gumishan and extends to the east and ends near the Gulidagh Mountain, in North-east of Kalaleh city. The actual length of the wall is not known because some parts of the wall are disappeared now but in the last century, Smith, in his aerial photogrammetric, considered the length of the wall about 170 km and others estimated it from 155 to 195 km. Upon the recent surveys, the height of wall varied from 2 to 5 meters in different places and its width estimated about 10 meters.

The engineers of the wall used ideal local materials to produce millions of fired bricks (loess bricks) to build the wall (Nokandeh et. al., 2008). The bricks which were utilized are so huge; each of them was square and of standardized size: 37 × 37cm on the west part of the wall, and 40 × 40 cm on the east part and mostly were 8 -11 cm thick (Figure 3), and were applied with mortar which were used by mixing mud, lime and straw (Moini, 1965).

Table1. The background of researches on great wall of Gorgan (les recherches précédentes à propos du grand Mur)

	Researcher	Date	Description
1	J. De Morgan	1886	The first studies
2	T. Arne	1945	The first scheme which identified 300 archaeological sites
3	E. Smith	1950	The first aerial photograph
4	M.Y. Kiani	1971	Study on aerial photos and 1:2000 maps, which thus discovered 32 Castle
5	M. CharlesWorth	1980	Continued fieldwork of M. Y. Kiani which identified 12 archaeological sites
6	Rychagov	1997	Determining the level of some parts of the wall from the sea
7	J. Nokandeh H. Omrani	1999	Identifying 42 sites at the confluence of the wall of Gorgan and irrigation system of Golestan dam
8	J.L. Schwenninger M. Fattahi	2005	Excavating The OSL and radiocarbon samples and determining the dating of the great wall (built in the 5th or, 6th century AD)

5 optically stimulated luminescence



Figure 3. The wall's bricks (des briques du Mur)

2. GARKAZ EARTH DAM

Garkaz earth Dam is an earth dam which is constructed on Gorganroud River and is located one kilometer northwest of a village which has the same name. The Dam's catchment is about 2213 Square kilometers. The height of dam is about 20 meters from the current riverbed. According to the site topography, the river is not so meandering in dam site because the river bank on both sides are observable thus the length of dam can be estimated. Therefore, the main part of dam is estimated 470 meters that 300 meters of it is still remaining (Figs. 4, 5).



Fig. 4. The location of Garkaz dam and features (la localit  et les caract ristiques de la digue Garkaz)



Fig. 5. Garkaz dam cross section (la coupe de la largeur de la digue Garkaz)

3. THE CONVEYANCE CHANNEL AND DITCH

A ditch and three channels were discovered during 2005 fieldworks. The ditch was located at the north facing-side of the great wall; its depth was estimated from 5 to 7 meters and up to 30 meters wide. Three channels have been discovered which they linked the ditch to Gorganroud River in three places, one of them conveys the water from upstream of Garkaz dam to the ditch called Chae Ghushan channel and others at 12 and 18 Kilometers downstream of dam site. The Chae Ghushan channel has had 11-12 meters width and 3-5 meters depth (Figure 6,7) (Nokandeh, 2006).

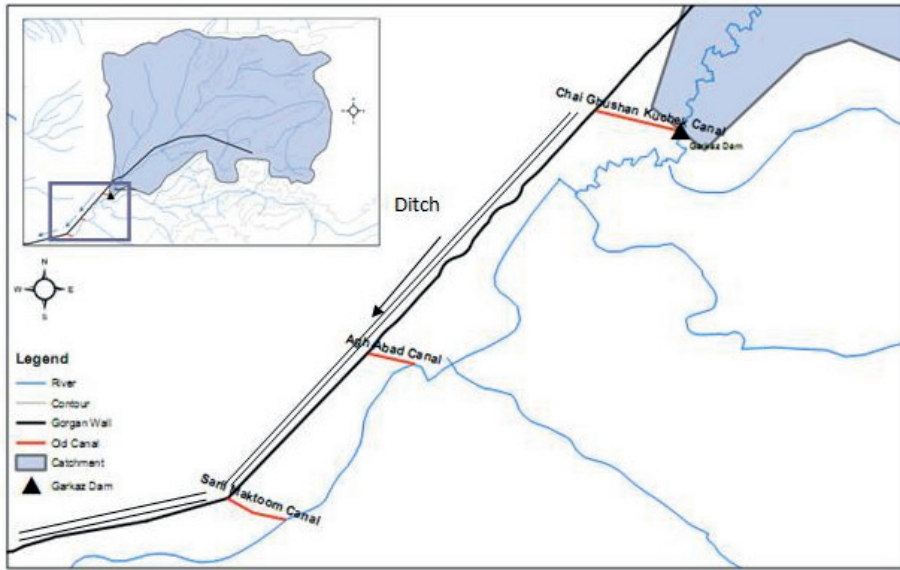


Fig. 6. Garkaz dam catchment, location of old channels, Garkaz dam and ditch (la région de l'eau de la digue Garkaz, la localité des canaux anciens, la digue Garkaz et le fossé)

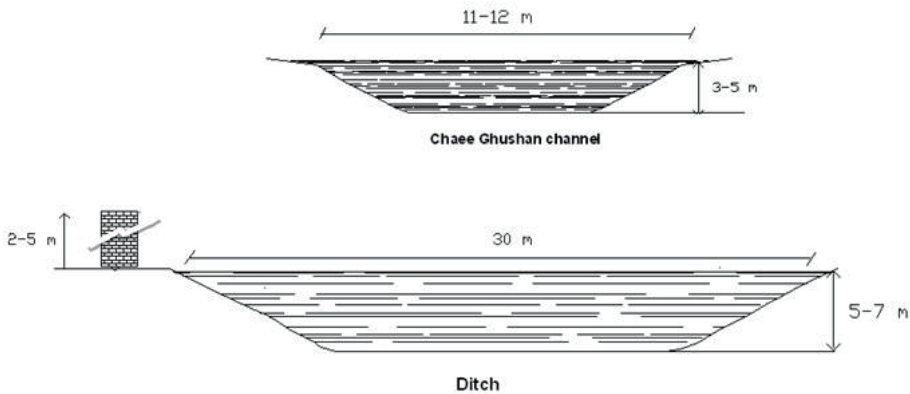


Fig. 7. cross section of Chae Ghushan channel and Ditch (la coupe de la largeur du canal Chae Ghushan et le fossé)

4. HYDROLOGIC AND HYDRAULIC INVESTIGATIONS

On normal way, hydrologic and hydraulic analysis of floods is required for designing of many parts of dam and flood channel's dimensions. In this case, inverse engineering method is applied to estimate the design flood of Chae Ghushan channel: so the maximum capacity of the channel compare with floods discharge. Consequently the discharges less than it as well as base flow ($2 \text{ m}^3 \text{ s}^{-1}$), were diverted through the channel. Observed flood discharge data of Haji Ghushan hydrometric station which is located on Gorganroud River at the upstream of the dam were analyzed by authors so the 2 to 1000 years flood were estimated from 84 to 932 ($\text{m}^3 \text{ s}^{-1}$) respectively.

Based on the Chae Ghushan channel's dimensions and the land surface topography, the channel capacity is estimated to be about 355 ($m^3 s^{-1}$), which is equal to a flood with 25 years return period. Because of the dam reservoir, the maximum flood discharge will be routed in upstream of dam, so the capacity of channel is more than 25 years flood. By neglecting the effect of reservoir routing, the Garkaz dam could divert maximum 25 years floods, therefore, two possibilities could be guessed for Garkaz dam, first; the dam had a weir which passed the extra 25 years floods water and second; it was without weir that in this case it was in high risk situation.

The channel conveyed the water to ditch. The length of ditch is 145 km from Chae Ghushan channel to Caspian Sea, according to topography, its slope is estimated about 0.0011 and considering it as a continues channel, therefore, the flow velocity and discharge calculate by flow resistance equations (Table 2).

The results show that the ditch needs about 510 ($m^3 s^{-1}$) (in 5 meter water depth) and 932 ($m^3 s^{-1}$) (in 7 meters water depth) to be full of water whereas it is between to 50 to 500 years flood. The depth of water for base flow (2 ($m^3 s^{-1}$)) is around 0.2 meter so the water depth was shallow at the most of days except the flood times. Therefore the ditch could not operate as a defending channel. on the other hand, according to the current evidence, the Gorganroud could not supply enough discharge to generate the 5-7 meters depth (to obtain to defending proposes) in ditch continuously, so there is no way unless the ditch was constructed as consequent storages with barriers, so These barriers made delay to flow water through the ditch and provide enough depth and also save the flood water not only for defending proposes but also for preparing drinking water for military people and their animals and irrigation.

The Combination of hydrologic investigation of the river and hydraulic of channel and ditch result that they had been designed as flood diverting and storing project at ancient era.

Table 2. Hydrologic and hydraulic investigation of Garkaz dam catchment, Chae Ghushan channel and the ditch (l'analyse hydraulique et hydraulologique de la région de la digue Garkaz, du canal Chae Ghushan et du fossé)

Flood return period (year)	Discharge ($m^3 s^{-1}$)	Calculated Flow depth in Chae Ghushan channel (m)	Calculated Flow depth in ditch without barriers (m)
Mean base flow	2	0.25	0.2
2	84	2.27	1.73
10	246	4.12	3.3
25	355	5	4.1
50	468	Out of channel capacity	4.74
100	588	"	5.4
500	932	"	7
1000	1112	"	

5. CONCLUSIONS

According to the hydraulic analysis conducted on the set of Garkaz dam, Chae Ghushan channel and the ditch, as well as integrating them with the results of archeological research, it can be concluded that this complex was able to divert the floodwater with less than 470 ($m^3 s^{-1}$) (50 years flood). Also, the ditch acted as a consequent reservoir to save the flood water along the wall to prepare a defending channel. The Garkaz dam, Chae Ghushan channel and ditch were the flood diverting system which was designed 1500 years ago.

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