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CONSTRUCTION OF LARGE DAMS IN THE CANARY ISLANDS [1]

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1. INTRODUCTION

More than 100 hundred large reservoir dams came to be constructed, in the Canary Islands (Fig. 1), between 1900 and 1980. From all these dams, the Soria’s vaulted dam, in the island of Gran Canaria, has to be highlighted (1558 km²). In view of its 132 metres high, the position of this dam is the 12th in the list of dams of larger height, in Spain.

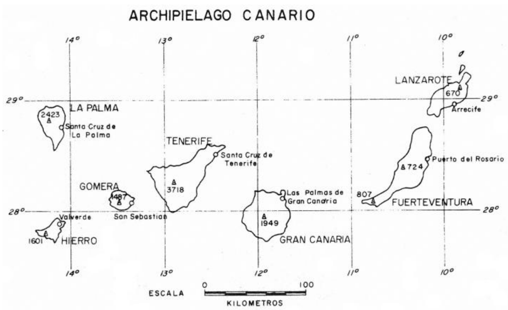

Fig. 1
Canary Islands (Spain)
Iles Canaries (Espagne)

[1] *Construction de grands barrages dans les Canaries*

Already in 1964, the Dam Safety Department engineer Manuel Alonso Franco collected, in a report about the condition of Canary Islands' dams, that "the number of constructions rated in the Directive as 'large dams' was huge in Gran Canaria" (Fig. 2). Also in the little island of La Gomera, where more than 18 large dams where constructed, the gigantic work of the people from the Canary Islands, in order to be able to get to collect and store the "liquid gold": water. In the Canary Islands, *land is the least of it. What is important is water.*

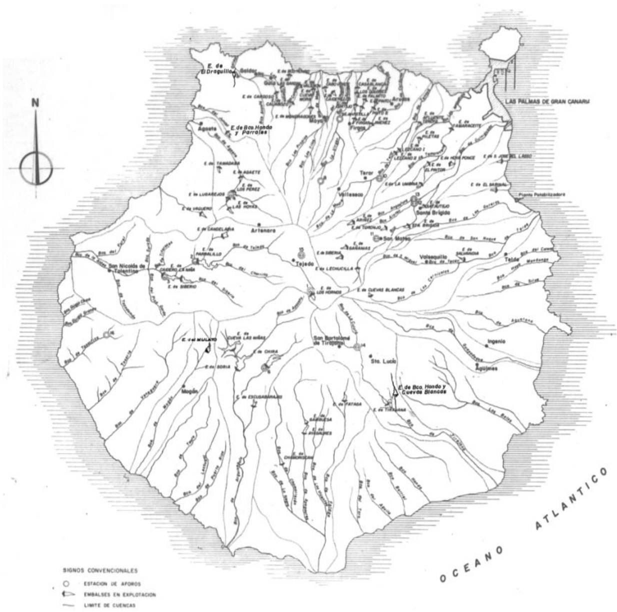

Fig. 2
Gran Canaria
Gran Canaria

In Gran Canaria, 65 large dams came to exceed 15 metres high. Although in the *great island of the dams* a high number of projects existed also and their execution did not get to be commenced. Many large dams remained lower than 15 metres high. Currently, still the exact number of large dams in the islands of Gran Canaria and La Gomera is unknown.

The construction of large dams in Canary Islands' Archipelago began before the first concessions were granted in the year 1904 for the dams San Lorenzo (Martinón) and Pinto (*the dam*), both in Gran Canaria. The need of counting on bigger water flows set aside for irrigation, lead excavating foundations, the first metres of walls and some supplementary works (openings into drains, channels, pipes, etc.) to be done before receiving the authorization of the Public Works Leadership of the Canary Islands region. The first final reconnaissances were those of the Pinto's dam (1910) in Gran Canaria (Fig. 3) y Coscos' dam (1982) in La Gomera. The first incident happened at the turn of the century, during the construction of the wall of the Dam of San Lorenzo. An *only crack and of an immemorial date.*

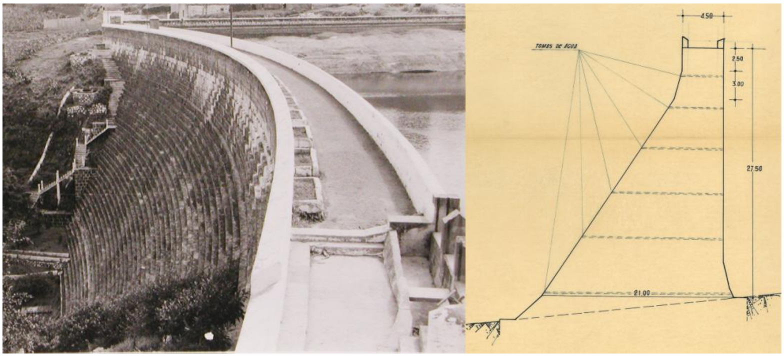

Fig. 3
Pinto (the dam)
Pinto (le barrage)

What had been imagined and what finally got to be constructed between 1902 and 1980 in the 7 islands of volcanic rock, acquires a bigger importance, if we remember what engineer Juan León y Castillo wrote in 1862, and aged only 24 years old, in the project of masonry dams in Tamaraceite's Gully (Gran Canaria) for forming reservoirs set aside for irrigation: "if the trial produces these favourable results, other many will be encouraged to do similar works in other analogue gullies that are in the regions and the face of its coasts uneducated and unproductive nowadays will change. Without any doubt, from the success of this venture, a new era for these islands will be born."

The typical profile of the 7 stepped dams in Tamaraceite's Gully was *"wrong"* It was a design similar to that of some dams constructed in the first half of the 19th century in France. A section of hydraulic masonry with the stepped upper water talus and less inclined than the lower water talus, which was almost vertical and flat. As engineers Díez-Cascón y Bueno say in their work *Ingeniería de Presas: presas de fábrica* (Dam's Engineering: manufactured dams) (2001), "about the suitability of this type of profile it is enough pointing out that turned 180º, that is to say, with the talus changed, its operating method would have been more adequate" (Fig. 4) [1].

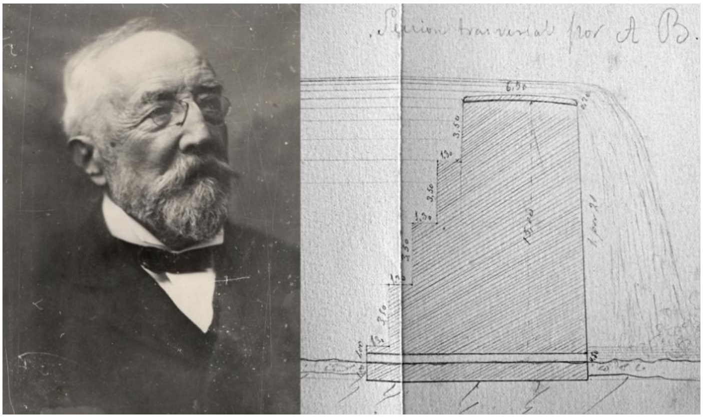

Fig. 4
Engineer Juan León y Castillo. Profile "wrong"
Ingénieur Juan León y Castillo. Profil "mauvais"

At the end, the trial was not achieved, although the young Juan León y Castillo was an engineer with a forward looking approach, because at the end, the *new era* started in the first decade of the 20th century with the development of new projects (San Lorenzo, Pinto, Los Cocos, Hormiguero, Casablanca, Marquesa, etc.) and the beginning of the construction industry, in the Canary Islands, with works that are "something more than structures." And the uneducated and unproductive coast lands became beautiful gardens.

2. DESIGN AND CONSTRUCTION OF THE DAMS

If the project of San Lorenzo Dam by the engineer Juan León y Castillo influenced enormously on those who did stone manufactured dams, until the 30s. Thus, we can assure then that the Pinto's dam marked the way to be followed by the other water manors, the communities or private farmers with water use rights, since it was the bigger hydraulic work of the Canary Islands, for years. The developing of this engineering work was a success for more than 100 years, for this reason, this old masonry lime wall and all the hydraulic masonry dwarf walls that cover the limits of the reservoir form a very important part of the hydraulic heritage of the Canary Islands.

In 1960, the engineer Fernando Ascanio y Montemayor collected, in a report about the stability of Hermigua's dam (La Gomera), his impressions about the methods acknowledged in the construction of reservoir dams, in both provinces of the Canary Islands. His description of the particularities that the construction of great dams offered in three stages was due to the "superb qualities of the foundation lots. Therefore, in the Canary Islands certain principals considered as basic and intangible in the mainland Spain had come to be exceeded."

2.1. OLD MASONRY DAMS WITH LIME MORTAR

The body of the wall of the old dam of Pinto was masonry constructed with lime mortar. The impermeability of the upper water facing was obtained with a simple plaster coat of lime mortar and cement, because it eliminates the setting retrace cracks. Pinto's dam was a tremendous success, that favoured numerous communities of famers with water use rights, water manors and private persons to decide to build great reservoir dams in the banana tree lands of the north coast of Gran Canaria (the dams of Marquesa, Hormiguero, Cardoso, Garzas, etc.).

According to Alonso Franco, as engineer in charge of the area of the Canary Islands of the Hydraulic Works Administration (old Water Central Commissioner), "the general characteristics of the old lime masonry dams in the Canary Islands are that they are curved in plan; that the triangular section with upper water facing is vertical and the water talus is insufficient to consider it as a pure gravity dam; that many of them lack spillway, and that there is an absence of manufactured drainage, inspection galleries and dewatering depth; and in spite of having a very little reservoir capacity, they have in general a great number of intakes and a wide transverse gallery in its bottom part for cleaning sediments."

In the Canary Islands, some elements such as the stepping of the lower water facing and the bottom area talus of the upper water facing, remember the criteria and the calculation procedures characteristic of the last third of the 19th century (Fig. 5) [2].

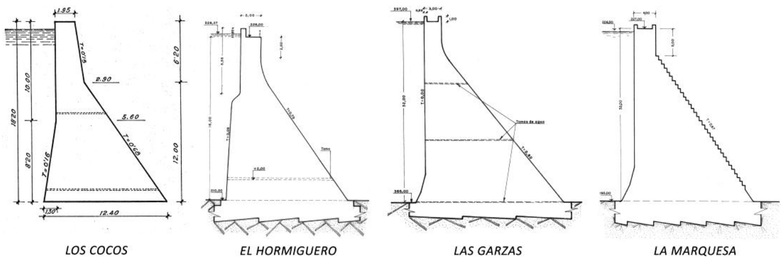

Fig. 5
Old masonry dams
Barrages en maçonnerie ancienne

With regard to the reservoirs, it is common to observe partial coatings with lime mortar and cement, in all the old dams. In the old projects, the geological descriptions by the dams' manufactures were scarce, but in the Canary Islands *if the bed was permeable, it was waterproofed.* Among the old dams of the archipelago, the great dam of Casablanca (Gran Canaria) stands out for its magnificent coating works.

It seems that the first geological report for the construction of a great dam by an expert was drafted by the Geology Professor Lucas Fernández Navarro, in 1927. It was entrusted to him with view to the construction of Cuevas Blancas dam, at Gran Canaria's top. Its initial project was from 1905. Regarding the central top of the island of the dams, Fernández Navarro wrote then that “it had a structure of predominant mass, maybe bad for searching in it underground waters, excellent for containing in it superficial water.” Finally, two big dams were constructed in the top of Gran Canaria. Los Hornos dam was a success, Cuevas Blancas, a failure, although the history of its construction is one of the most interesting of all over the Canary Islands (Fig. 6) [3].

Fig. 6
Cuevas Blancas
Cuevas Blancas

Subsquently, the *Docteur en –sciences–* Jacques Bourcart prepared a geology report of the tight where the vault of Soria was finally constructed. Bourcart did it for a gravity dam curved in plan 90 metres high with foundations. In spite of both old reports, many projects continued presenting meager geology descriptions, in the following decades.

Among the impressions contributed by Ascanio y Montemayor about the construction of dams in the Canary Islands, three fundamental reasons for which "failures had not been registered in dams that were constructed without complying with the conditions demanded, at that time." The first of the reasons was that "all the old dams had been founded on powerful layers of basalt, trachyte or sound-stone, of a great capacity. Thus the underpressure that would show up in other permeable lands was avoided." The second of the reasons was in the fact that "the private initiatives had not turned to builders with enough auxiliary means to finish them quickly. The construction of this works of stone craft, on the contrary, had been slow, which caused the lime mortar to have enough time to harden receiving the prolonged contact of the air." Lastly, that "carrying out the plaster coat with mixed, lime or cement mortar, and not only of cement, produced a complete and lasting impermeability of the upper water facing, in the old dams."

The incident of the dam of San Lorenzo (Fig. 7), in the hydraulic year 1903-1904 occurred when the water housed in a 12 metres high wall in construction exposed and important crack in the land: *a unique crack and in a immemorial date*, according to what the Public Works Engineer authorized the concession in 1904. The second incident was in March, 1988, when water exposed the old natural crack again. It seems that during the overlying of the primitive wall in the 60s, the eye reconnaissances up to 28 metres practiced by the Public Works engineers of Las Palmas in the early 20th century were disregarded. The crack in the land at the turn of the century became a bad foundation of primitive dam [4].

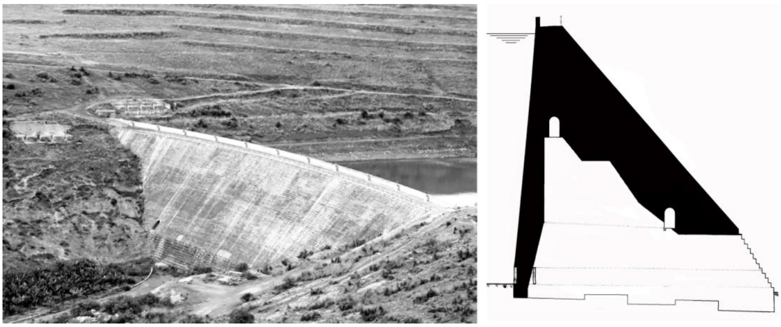

Fig. 7
San Lorenzo (Martinón)
San Lorenzo (Martinón)

But it was the 21 of February of 1834 when the sudden breakage of El Toscón's dam took place in the San Lorenzo municipal district (Gran Canaria), causing the death of 8 people among children and adults. Water flew violently through the gully completely destroying the La Hoya's bridge, of the road that leads to Teror Town from Las Palmas, several houses of stewards and some banana trees lands. This tragedy was named then as the *terrible Disaster of El Toscón*.

The remains of the wall, a material that is available for us, also is part of the hydraulic heritage goods of the Canary Islands. From the photograph of the walls outline, where a top dwarf wall in the upper water facing is seen, some interesting conclusions can be drawn. According to the newspaper *Diario Republicano Federal*, it was “a disaster provoked by the greed of those who measure their income for pleasure through the modulus that points out the water entry in their dams.” Liquid gold (Fig. 8).

Fig. 8
Catastrophe d’El Toscón

2.2. DAMS WITH LIME AND CEMENT MIXED MORTAR

The second stage of great reservoir dams in the Canary Islands arises when the lime and cement mortar starts to be used in the body of the walls of the dam. The difficulty of acquiring the necessary cement and the circumstance that the lime was of excellent quality was what motivated the binder to be used preferably. Los Pérez dam in Gran Canaria, with mixed mortar up to 30 metres high and lime mortar until the top, was for some years the taller dam of the islands (45 metres on the bed).

One of the most important dam manufacturers in the Canary Islands, the engineer Julio Alonso Urquijo, explained in the reports of the Projects that “the use of mixed mortar was meant to accelerate the forged wrought of the lime mortars in walls of great thickness, as well as the increase of resistance” (Fig. 9). He also wrote that “it adopted the gravity dam profile ordinarily used, which must resist, under its own weight, exclusively, to the force of water. And which with such calculation basis, the fact that the walls have a straight or curve form in plan, but which I preferred projecting them in circular arch, obtaining as well an additional factor of safety." This explains why there is a very high number of dams with curved plan in the Canary Islands, especially in Gran Canaria. Only some old masonry dams were constructed with straight plan, although they had previously been designed with curve plan (e.g. Cuevas de las Niñas). [5]

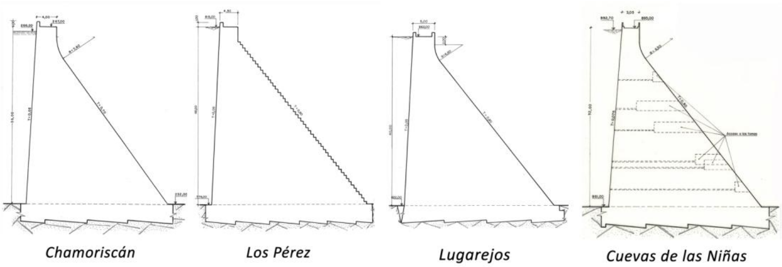

Fig. 9
Walls of great thickness
Murs de grande épaisseur

After the construction of the little dam of Los Rajones, in 1942, as a trial, in 1943, a dam wall started to be constructed in the top of Tamadaba's massif, according to the typical stone attached rockfill dam profile in its body and a hydraulic masonry and plaster coat impermeabilization screen with bastard mortar. Tamadaba's dam stopped being constructed in 1954 when there was one metre left for its levelling. This large dam is 17'70 metres high on the bed, 19'70 on the foundations and 163 metres of length on top per 6, wide. A massif of stone craft. [6]

In 1950, engineers José María Valdés y Díaz Caneja, José Luis Fernández Casado and Manuel Lorenzo Blanc, as members of the Public Works Geology Consultancy, made a visit to Gran Canaria in view of the construction of El Caidero de la Niña's dam, in the most important gully of all the Canary Islands, by far. This visit to La Aldea's Gully was made, in order to pass judgement about the conditions of the land, where a reservoir dam, which was going to be constructed, was going to become a very clear example of the indirect and substantial benefits that a hydraulic use work well conceived produced. With the construction of the dam, not only did the builders expect to broaden noticeably the cultivation lands and to improve La Aldea de San Nicolás' outgoing communications, by means of the subsequent construction of a "little pier" or the "refurbishment or substitution of the Andén Verdes road", but also cleaning up effectively by regulating and lessening the impetuous avenues of the gully. The sanitary situation was truly pitiful, due to the fact that the gully's ponds were the cause of endemic malaria and of the propagation of typhic infections. The infant mortality reached the proportion of the 40 per cent.

In 1964, the engineer Manuel Alonso Franco highlighted that "the dam of El Caidero de la Niña stepped aside the classical construction of dams in the Canary Islands, because it met a more modern conception." Thus, it was constructed with mass concrete with cement binders Portland (brick concrete) It had transverse contraction joints and three longitudinal visit and inspection galleries. Its firm limp spillway has three openings and it is situated in the centre of the dam, equipped with a launching springboard. The type of this great dam straight plan gravity and height of 46'40 metres on the bed (Fig. 10).

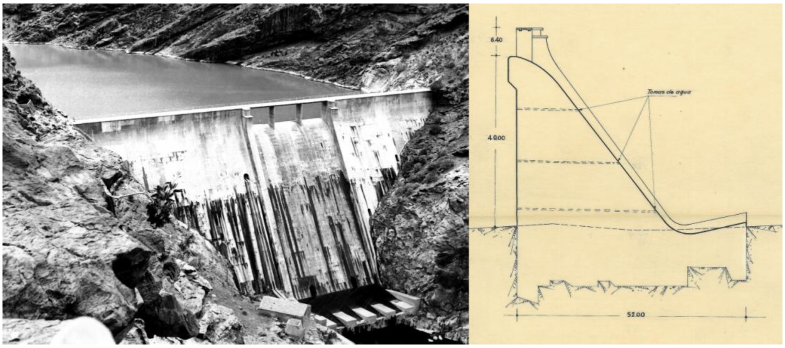

Fig. 10
Caidero de la Niña
Caidero de la Niña

In a report dated in 1962, about a project of three stepped dams for water storage coming from Tejeda's Tunnel (Gran Canaria), the engineer José Luis Fernández Casado mistrusted cyclopean concrete, because "he had seen several times how it became a bad concreting masonry that could almost be described as dried masonry."

Between 1902 and 1961, 41 great masonry dams had been constructed in Gran Canaria. The banana trees, the great consumers of water, were mainly responsible for this high number of great dams. The supplying of Las Palmas city and of Puerto de la Luz remained in the second place. However, the number of great dams constructed in Gran Canaria in only 60 years, acquires more importance, when we combine it to the number of ponds (some 5.000), wells (some 800 drilled 78 km), galleries (some 420 with 140 km), diversion channels (Fig. 11) or tunnels (153 km) and distribution pipes (534). Numerous hydraulic ventures that say a lot in favour of the *insular diligence*, specially the private initiatives.

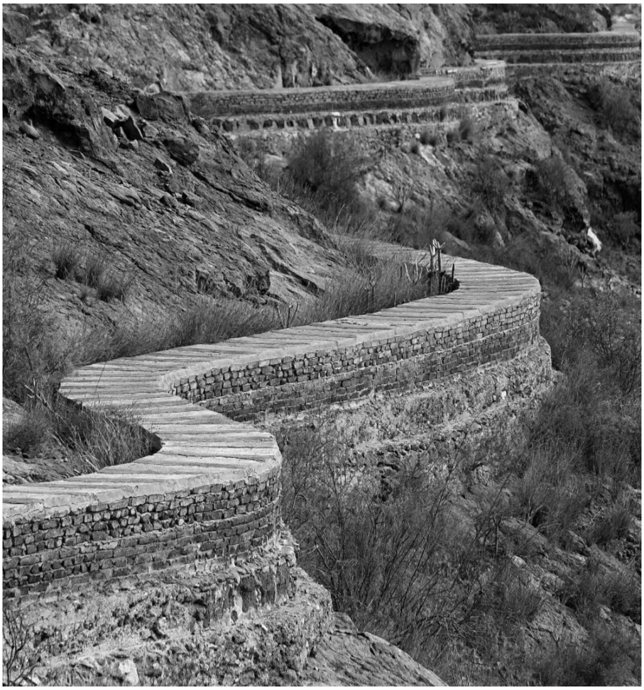

Fig. 11
Channel of Soria
Canal de Soria

In the 60s, not only were many masonry dams with bastard mortar (lime and cement) finished, whose works had began in previous decades, but in 1962 the construction of the vaulted dam of Soria started (concrete) and some masonry dams were constructed only using mortar cement, concrete screen and drainage pipes. In the islands, there was a great tradition in the construction of masonry dams, especially in Gran Canaria. [7] Towards 1964, in La Gomera, 7 great old dams had been constructed by privated builders and 7 dams by the Hydraulic Services. The private dams with curved plans and lime masonry. The more modern dams with straight plan and cement mortar masonry. All of them without drainage in their body and in their foundation.

According the reports of 1964 by the Dam Safety Department (engineer Manuel Alonso Franco), "in all the masonry dams in the Canary Islands *it is supposed that the density of their compositions has a relatively low value. We do not think that it is exaggerated believing that many of this constructions have densities that can range from 2'10 to 2'25 Tn/m³."* "A more favourable hypothesis than that possible", said the engineer José Luis Fernández Casado.

The study made between 1970 and 1971 by the engineer José Sáenz de Oiza, about the state of Las Cuevas de las Niñas Dam resulted in a very low density of the composition, lower than 2'0 Tn/m³ and close to 1'8 Tn/m³. After a visit to the Canary Islands, the engineer Federico Macau Vilar (SGOP) wrote in a note "I do not like the Cueva de las Niña at all." It still is the only real scale model for the theoretical study of stability of other dams in Canary Island's Archipelago (Fig. 12) [8].

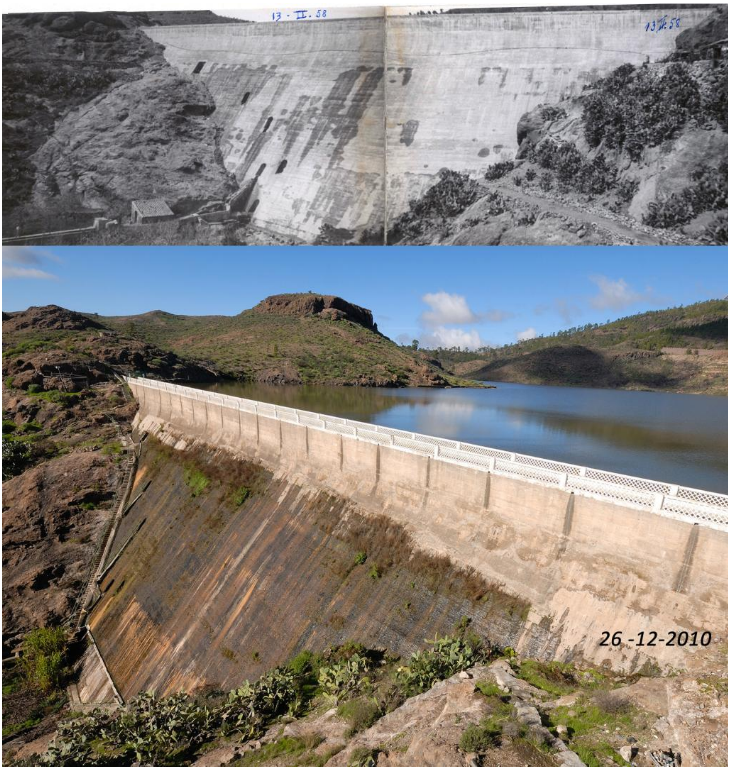

Fig. 12
Cuevas de las Niñas (*Majada Alta*) 1958 – 2010
Cuevas de las Niñas (Majada Alta) 1958 - 2010

The engineer Fernando Sáenz Ridruejo says that "as a result of the reports of 1964, in which Alonso Franco revised their safety conditions, all these dams entered in way of rationality [9]. In fact, the first critical judgement do the stability fo the great masonry dams constructed in the Canary Islands, by the dams builders Fernández Casado and Alonso Franco, influenced very much in the development of some projects of great dams, as well as in the subsequent construction of the brick concrete with facings finished in concrete (Parralillo, Gambuesa or Fataga by Gran Canaria's Inter-island Council). But it was more determinant for the overlay with masonry composition in old dams, due to the incentives granted by the State to the owners. The overlay of the dams of San Lorenzo or la Umbría, both in Gran Canaria, constitute a good example. However, the overlay El Mulato's dam was with concrete (Fig. 13).

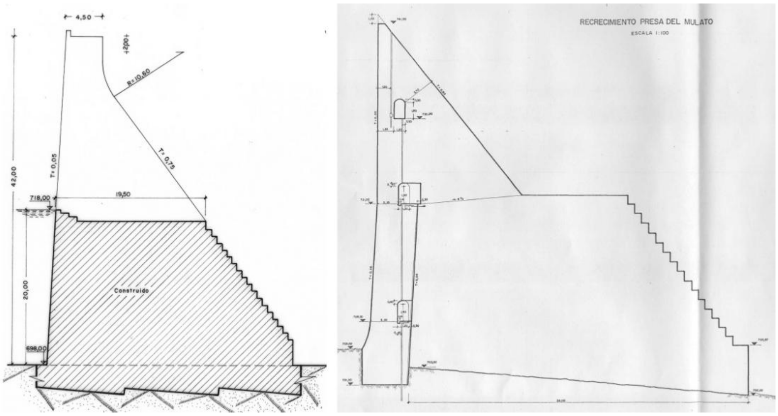

Fig. 13
El Mulato
El Mulato

According to the overlay projects and works in some reservoir walls, and due to the absence of inspection galleries, of composition's drainage and bottom dewatering in the dams constructed with lime or bastard mortar with rough ashlars with a reduced density, the engineers explained in Madrid in 1966 that "the civil service should feel concerned with the safety of all the constructions with masonry compositions, especially in Gran Canaria and La Gomera due to the high number of dams which entered in the classification of great dams." The general solution then proposed by the Dam Safety Department was that "the State should take charge of its structural guarantee, being met by the necessary auscultation and reinforcement expenses in the works whose owners lacked resources and suitable technical staff."

2.3. MODERN DAMS

In 1972, ended up the construction of Soria great dam (1959), a double curvature dome of 132 metres on foundations (Fig. 14) [10]. A private initiative achieved the construction of the only vaulted dam in the Canary Islands, in a tight were Gran Canaria's Inter-island Council had previously projected a 90 metres high curved plan gravity dam with foundations (1930) and a hydraulic concrete vaulted dam of a 70 metres high fine wall with foundations (1935)

Fig. 14
Soria
Soria

The was a project by the engineer Saturnino Alonso Vega to build another vaulted dam in Gran Canaria, in a tight of Siberio's Gully (1968) Its height over the foundations was 78'50 metres, while the top had a length of 190 metres with 5 metres wide. Its reservoir volume was 4 800 000 m³.

In 1972, the thick vault was awarded to the company Dragados y Construcciones, whose representative in the Canary Islands was the engineer Emilio Benítez Pascual, but finally a refurbished project was made in 1973, that defined a rockfill dam solution with asphalt screen in the upper water facing and moved the initial tight some 300 metres lower water. Finished in 1978, its loading occurred suddenly during the *extraordinary storm* of January, 1979.

The oral tradition collects that Tamadaba's dry masonry dam was emptied after its first loading. It was immediately repaired. In 1979, happened the same to Siberio's Dam, after the initial breakage of the plinth due to its scarce sizing and its bad housing. The structure was repaired by means of actions that were carried on until 1984 (Fig. 15).

Fig. 15
Siberio
Siberio

Also during the third stage, some concrete dams, such as La Encantadora in Las Gomera (gravity) or Ariñez's dam in Gran Canaria (abutments), although that years the Dam Safety Department put every effort in the design and construction of dams of separate materials. Alonso Franco says that "their opportunity was denied under the belief that the talus of its wet facing minimized to the already meager of its vessels." We already said that, in the Canary Islands, *land is the least of it, what is important is water.*

Most of the great dams of separate materials constructed in the Canary Islands are rockfill dams with an upper water screen in the facing. Thus, in La Gomera island the dams of Amalahuigue and Mulagua were constructed, both by the Inter-island Council. But in Gran Canaria, in the mouth of Tirajana's Crater, a rockfill with central core was constructed (Fig. 16). The primitive projects to construct a great dam in the tight of Tirajana's Gully had been gravity projects.

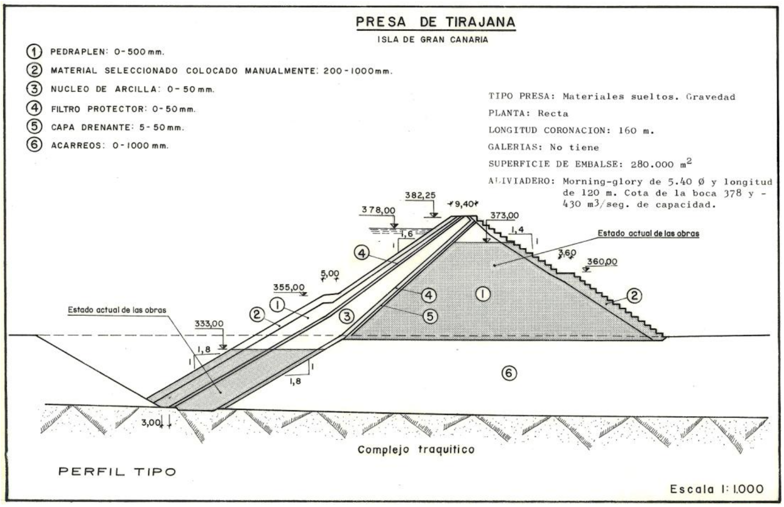

Fig. 16
Tirajana
Tirajana

In the superb article *Utilización de materiales pliocuaternarios en presas de materiales sueltos* (Use of pliocuaternary materials in dams of separated materials) (1979), the engineers Gómez Laa, Alonso Franco and Romero Hernández highlighted that “Tirajana is a rockfill dam that makes the most the alluvial plan for berms and a cleyey colluvium from basalt, for the impermeabilization.” In one of the books by the engineer José Luis Fernández Casado, the following can be read: “success (there are few comments) observing that the core is central, TIRAJANA.”

3. HERITAGE OF THE CANARY ISLANDS

The old Official Catalogue of the reservoir dams of height higher than 15 metres of the Ministry of Public Works (1962), says that “Spain is one of the countries with older tradition of dam works.” It also says that “from the 283 great developing dams at the end of 1961, 48 have been catalogued in the Canary Islands. This figure is more than enough to weigh up the importance of the works done in the part of the Insular Spain.”

By observing the list of the 48 dams constructed in the Canary Islands between the years 1902 and 1962, adding, among other, the Hormiguero dam and Toscon’s dam (Granadillar), we remember right away the words that Joaquín

Amigó left us in 1953: “traveller, when you go through our road and you contemplate these cultivated lands, think for a moment in the work taken to obtain the water to water them and that the said apatheticness of the people from the Canary Islands is a legend invented by those who do not know us, although we modestly, develop it.”

If, as engineer Federico Macau Vilar said in his magnificent book El Problema Hidráulico Canario (Canary Islands Hydraulic Problem) (1960), “water is in any part of the Earth one of the vital essential factors; its abundance of scarcity define determined ways of living and character. Not only does water make the land vary, but also the living standard, the type and development methods of Agriculture and Industry, and even the way of being and thinking of men”; we can then think and say that in the diversity of Canary Islands landscape the great cyclopean masonry dams are not only great hydraulic works of the Canary Islands, but also, the great heritage and cultural elements of that old way of doing agriculture (Fig. 17). As the dam manufacturer Alfonso Cañas Barrera said in 1961 “raised almost to the level of gardening.”

Fig. 17
And even the way of being and thinking of men
Et même la manière d’être et de penser des hommes

CONCLUSIONS

In the 21st century, not only must we acknowledge the obvious historical value that Canary Islands’ dams, but to carry out an important revision of the state they are in, specially the masonry dams. In the past, the Dam Safety

Department engineers said about the Canary Islands that the civil service should feel concerned. Now, we continue having a civil service, but we do not have a Dam Safety Department.

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SUMMARY

Over 100 hundred large dams were constructed in the Canary Islands (Spain) between 1900 and 1980 (65 on Gran Canaria Island alone). Most of these dams were built using cyclopean masonry, but a few rockfill dams and a single arch dam were also constructed. The historical and cultural value of these great structures must be acknowledged, but their condition must be inspected. In the Canary Islands, there is no Dam Monitoring Department.

RÉSUMÉ

Dans les îles Canaries (Espagne) ils plus de 100 grands barrages ont été construits entre 1900 et 1980 (65 sur l'île de Gran Canaria). La plupart des barrages sont en maçonnerie cyclopéenne, mais il existe également quelques barrages en enrochement et seulement un barrage-voûte. Nous devons reconnaître la valeur culturelle et historique de ces grandes ouvrages, mais il faut également vérifier leur état. Aux Canaries, il n’existe pas de département de surveillance des barrages.