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Small hydro award winner

Profile of the Canedo hydro project

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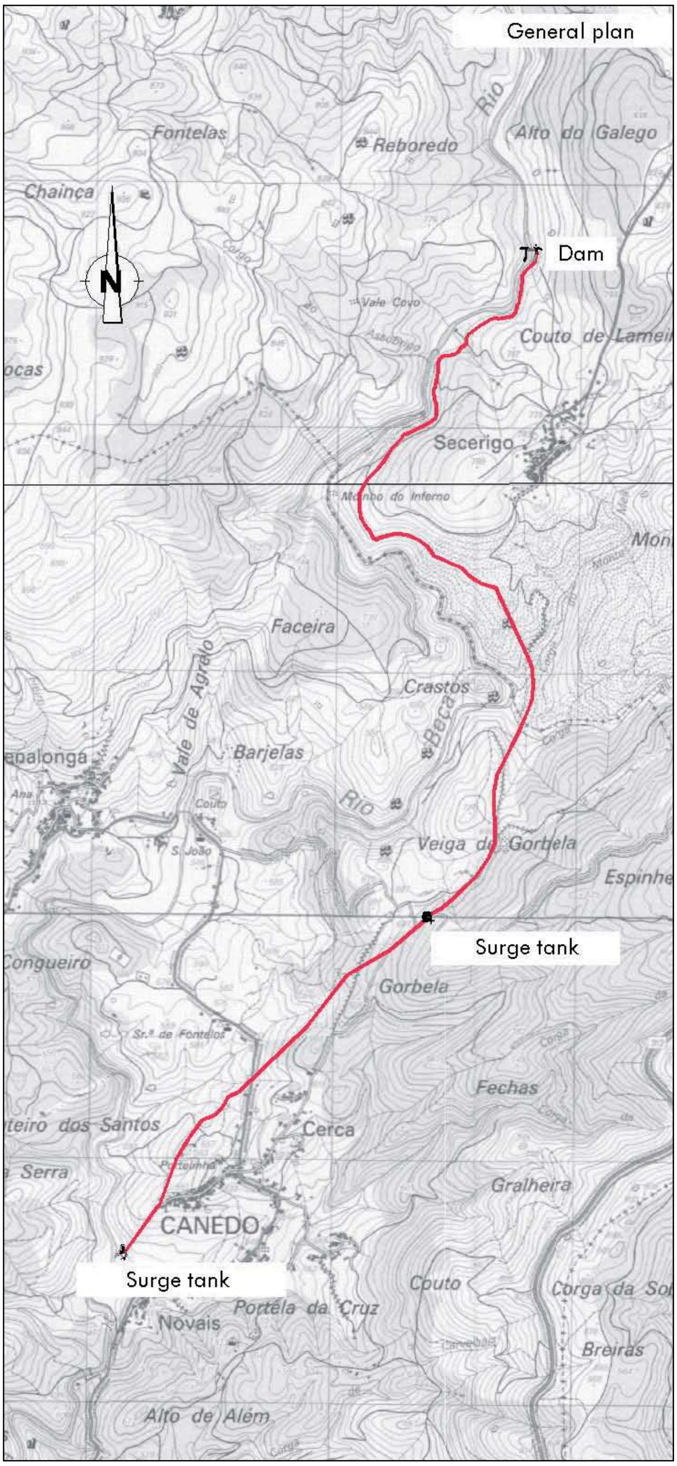
Canedo hydro plant – an award-winning design

The Canedo hydro power project in Portugal was named the winner of IWP&DC's first Small Hydro Award in October 2009. Here you'll find an in-depth description of this impressive project and discover why readers felt it deserved to be named the winning project

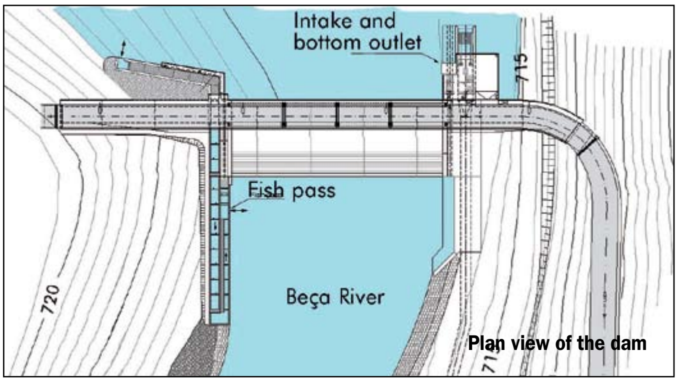
CANEDO hydro power scheme is a small hydro project developed on the Beça river in northern Portugal. The scheme is located in the Trás-os-Montes region, extending 5.5km through the municipalities of Boticas and Ribeira de Pena.

The first studies for the Canedo project were carried out in 1992. Due to several setbacks, mostly related to the licensing process, the 10MW plant only went on line in December 2008. The scheme is owned and operated by RPGlobal Portugal (RPG), a subsidiary company of the RPGlobal Group. Aqualogus carried out the project's feasibility studies and design work.

The Canedo project has some specific features that make it an unusual project in RP Global Portugal's portfolio. The river Beça is not only used for irrigation purposes, but is also known for its rich trout community, with a trout farm actually located upstream of the Canedo project's intake. The powerhouse is located near a village, upstream of a river beach, and is a very visible part of the landscape. Lastly, even though the scheme's infrastructure is not located in an environmentally protected area, the site was actually given conservation status. These issues meant there were serious doubts about the project's viability, and had significant influence in several design and management options.



Above: General view of the scheme



The Trás-os-Montes region is an interior zone of the country, with a depressed economic condition, mostly due to population migration from the fields to the urban areas. As a consequence, the residents are mostly older people who rely on agricultural work and cattle breeding. It is, however, a humid zone, with abundant water resources.

The River Beça is a tributary of the Tâmega River, which itself is a tributary of the Douro River, the most important watercourse in north Iberia. The watershed is mostly occupied by forest and pastures and has an area at the intake section of 114.5km^2. The river has an average bedslope of 3% in the part used by the scheme. The median average annual rainfall is 1350mm, which originates an average flow estimated in 815mm (2.95m^3/sec).

The scheme comprises a dam, low-pressure circuit, surge tank, penstock and powerhouse. The installed power of 10MW is accomplished with a turbine flow of 5.4m^3/sec under a net head of 226m.

The gravity dam section is 14.8m high above foundation and has a crest length of 92m, including a bridge over the spillway. The intake and bottom outlet are located on the left side. The 80m long fish pass and the reserved flow outlet are on the right riverbank. The lake created by the dam floods an area of 4ha.

The hydraulic circuit has a first part in DN1800/1600 pipe, a 24.5m high surge tank and a DN1500/1400 steel penstock. All the pipes are laid in trench. The surge tank is a cylindrical concrete structure with 11m internal diameter.

The powerhouse has one horizontal Francis unit and is located near a river beach, close to Canedo village. The building was subject to a thorough architectural study, which focused on integration with the striking surrounding landscape and interaction with the visitors. The architectural study of the building was subject to a concept contest in an architecture college.

Project history

Canedo has had an alvará (old water license) since 1993 and is one of the oldest projects developed by RP Global Portugal. In 2002 the development process became stagnant because plans for a dam would have flooded the fish farm upstream, meaning a flap gate would need to be installed at the dam crest. The flap gate project version was developed later that year.

A new Technical and Economical Feasibility Study (TEFS) and Environmental Impact study were needed for the project, and these were executed and delivered in 2003. In the reformulation of the TEFS, considering a new tariff system, it was discovered that a smaller water volume could be stored in the reservoir, lowering the maximum operation level. This meant the project would not affect the fish farm.

Following approval, the new TEFS and Environmental Study were issued for public consultation. During this process there was significant opposition from the local irrigation associations, who were concerned that the project would withdraw water necessary for irrigation purposes.

To address this, a long and difficult negotiation process was initiated with the authorities, municipalities and irrigation association's representatives. During this process, more studies were performed to investigate flows in the irrigation channels.

These negotiations concluded in 2005 in a meeting with all the stakeholders, culminating in August 2006 with publication of the project's Declaration of Public Interest. However, a law change in 2007 meant it became necessary to obtain a concession contract, in which the construction license would be embedded. This meant a firm contract was only approved in 2008. During this process, support and involvement of the municipalities was vital.

Design features

The Canedo dam is laid on a solid granite foundation. The geological site examination had anticipated a layer of loose blocks on both riverbanks. Given the heterogeneity of the subsurface layers, it was decided only two machine excavated test pits would be carried out. During construction, the project geologist supervised all excavation work, and no relevant problems were reported.

The fish pass was designed to operate continuously throughout the year and with satisfactory performance in every reservoir operation level, given the importance of the trout community on the Beça River. This requirement led to a design where part of the structure – with four orifices – is implanted upstream of the dam. The orifices are regulated by electrically manoeuvred sluice gates that automatically open and close to control the flow within acceptable limits, whatever the level in the reservoir. When a flood occurs, a 1.1x1.6m^2 sluice gate isolates part of the pass downstream of the dam.

The region has an ancestral winter irrigation method called rega de lima for protection against frost, where the water is conveyed through long open channels called levadas. The dam automation scheme guarantees the release of the necessary irrigation flows in order to accommodate this concurrent water use. The flow is diverted through an independent DN700 circuit and is released at the downstream entrance of the fish-pass to better attract the fish.

One particular design option concerns the architecture of the powerhouse building. Given its prominence on the landscape, and the fact that it is close to a village and river beach, led RPG to give special attention to the layout. It was decided that the building would have simple forms and should allow interaction with visitors, ideas that emerged from the architectural concept held at the university. The final layout is a cubic building that has a group of window openings by the riverside facade. The facade has a balcony visible from a riverside path, allowing walkers a full interior view of the powerhouse.

Construction phase

The construction works were divided into several contracts, including one for the civil works and another for the pipe installation. Other contracts were for the turbine-generator supply, electrical installations, pipe supply and hydro-mechanical equipment. Construction was scheduled for execution from January to December 2008.

RPG bought the sites for the construction of the dam, the surge tank, the powerhouse and the roadway. The pipe routes were negotiated as right-of-way contracts.

Dam

Works started in February with surveying and construction of site facilities. The first works at the dam site were clearance, topsoil removal and improvement of an existing rural pathway to allow access for the earthworks machinery. A small earthfill was built to divert the river to a narrow channel excavated in the rock on the right riverside. During foundation excavation some drill and blast was required. Once the rock surface level was reached, it was cleaned up with water jetting.

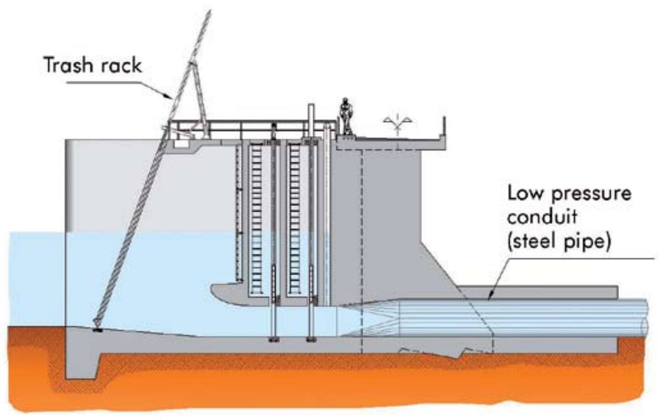
The dam spillway has a total length of 36.9m and is divided into five blocks. The two extreme blocks are 4.3m long and the three core blocks are 9.3m long. The concrete was pumped in 1m high layers and the spillway roller bucket and crest shapes were handmade and were built without any facing formwork. The dam foundations have a 1.5m high concrete layer under the roller bucket. To build the right wall abutment and the fish ladder, the river was diverted across the dam core block which was left open until the flow could be diverted through the bottom outlet.

The water intake at the left abutment is a 2 x 1.8m^2 opening, protected by wing walls and a trash rack. There is an initial 56m long steel pipe embedded in the abutment and connected to the Glass Fibber Reinforced Polymer (GFRP) conduit with a special fitting.

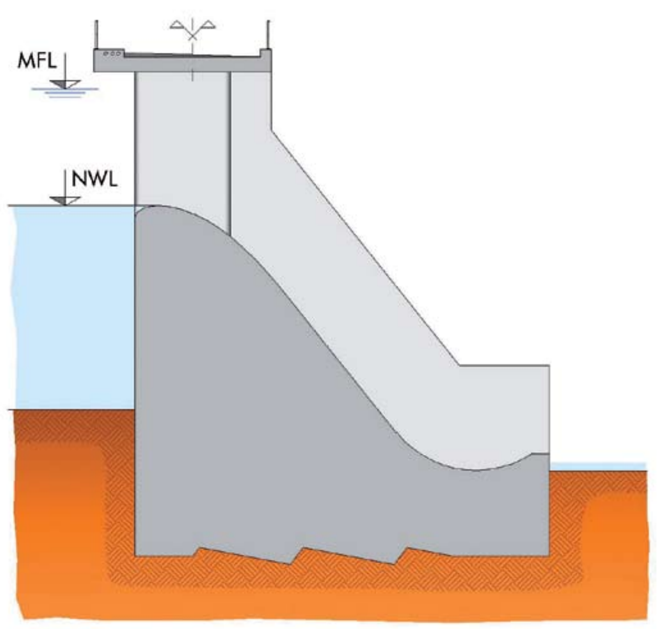
Once the abutments, the fish ladder and the riverside walls were finished, the contractor built three piles in the spillway crest to support the bridge deck. Initially designed as a cast-in-place reinforced concrete deck, the bridge was executed with precast concrete beams and precast slab panels.

Low-pressure pipeline

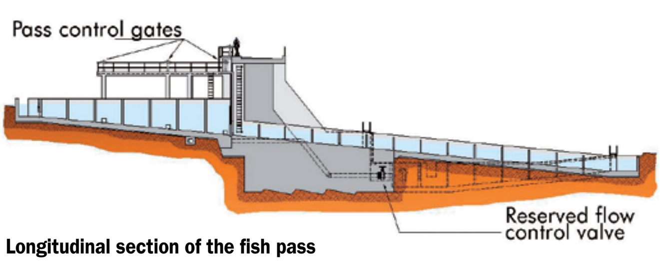
The 3680m long low-pressure circuit was originally designed to be concrete Bona pipes. Considering the anticipated delivery time, the contractor proposed a change to GFRP Flowtite (Amitech) pipes. The



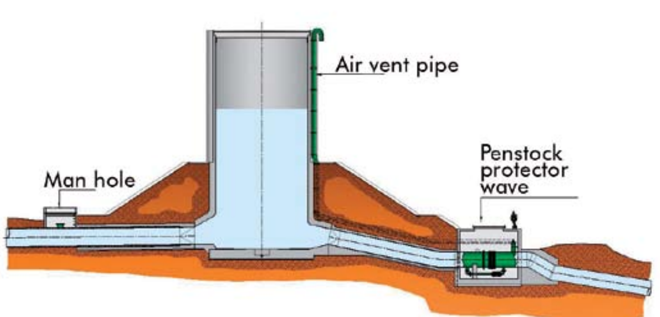
Intake section



Spillway section



Longitudinal section of the fish pass

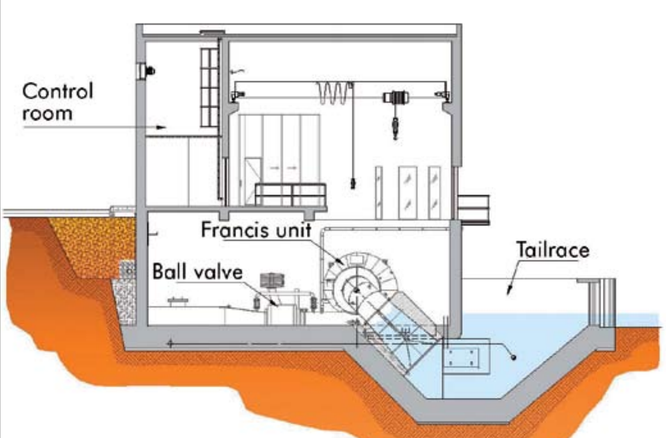


Surge tank longitudinal section

contractor's team prepared a new layout for the overall route of the pipeline to be approved by the design team. The pipes were delivered on site in July and installation began immediately.

Surge tank

The surge tank was the first concrete structure to be completed. The structure, with a total height of 22.55m, was built as 2.75m high complete circular walls with a Peri Rundflex formwork system. The surge tank has a first 0.6m thick, 9m high wall and a second 0.3m thick, 13.55m high wall. Each concrete joint section was striped with a waterstop embedded in and running continuously through the circular wall perimeter to prevent leaks. The concrete plane roof structure was finished with precast concrete beams and roof slabs.



Powerhouse

Project summary

Location	**Trás-os-Montes region, Portugal**
Water source	Beça River
Catchment area	114.5km^2
Mean annual precipitation	1350mm
Mean annual flow	2.95m^3/sec
Maximum turbine flow	5.38m^3/sec
Monthly reserved flow	170 – 700 l/sec
Gross head	242.5m
Design net head	226.44m
Maximum power capacity	10MW
Capacity factor	33%
Average annual energy	28.6GWh
Operation	Run-of-river
Intake	Frontal intake located on the left side of the dam; 2 x 1.8m^2 orifice, protected with vertical trash rack and automatic cleaner
Waterway	3.7km low pressure DN1600/1800 plastic Flowtite pipe; concrete cylindrical surge tank, with 11m internal diameter and 24.5m height; 1.9km long DN1600/1400 steel penstock
Powerhouse	Cubical concrete building, with two levels
Turbine	1 horizontal Francis unit
Generator	11.1 kVA direct coupled synchronous
Switchyard	6.6kV to 60kV
Transmission line	30km
Connection	National grid
Owner	RpGlobal Portugal
Designer	Aqualogus
Project Manager	Eng. Guerra Daniel, RpGlobal Portugal, d.guerra@rp-global.com
Design Team leader	Eng. Francisco Freire de Carvalho, Aqualogus, Engenharia e Ambiente, francisco@aqualogus.pt

Powerhouse

The powerhouse structure layout was considerably improved during the earthworks. To avoid the construction of large flood protection walls, a new roadway was designed to access the powerhouse. The powerhouse site was a square-area excavation; the soil was removed in layers, similar to a levelling process, because there was no access to off-road dumpers until April. Once the road was built, the foundations were finally set up 5m below the water table, with several different sections.

The powerhouse is a two-floor building, one for the electrical equipment in the basement (471.5) below the water level and a technical floor for the control room (478.5). Before the upstream wall was built, the first steel pipe was embedded in an anchor block. Once the concrete works were concluded by mid September, the mobile crane was lifted and passed through the 7x 4m^2 rectangular opening on the roof.

Before the end of September the major equipment of the turbine was delivered on-site and installed by a team from VA Tech Hydro (now Andritz Hydro). The generator was installed before the end of October and, as with the other heavy and over-sized equipment, it was installed through the roof opening.

Penstock

The steel pipes for the penstock were delivered by the end of May, but remained stocked until the end of July, when the hydro-mechanical contractor started the installation and welding works, after overcoming initial difficulties with access to the construction sites.

It is remarkable that a considerable extension of the pipeline was buried across the small backyards inside the Canedo village, an old countryside community dedicated mainly to farming and cattle. The existing accesses were pathways too narrow to transport the six tons pipes, thus two extra roadways were built along the access road. Stocked 1.5km away from Canedo, the pipes were transported on an adapted truck to the site.

Where the hillsides were too steep for the truck, the pipes were transported by an hydraulic excavator.

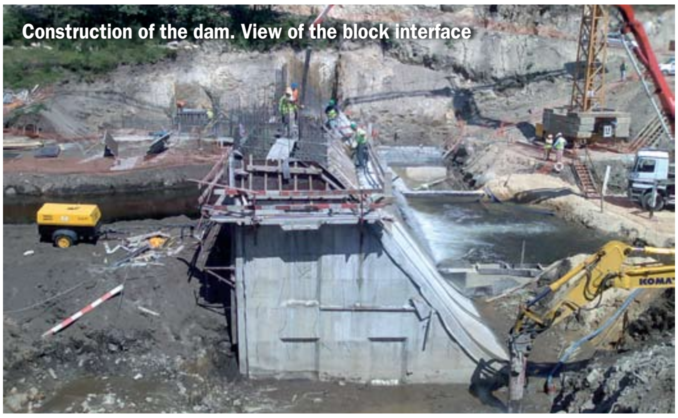
Environmental issues

The Canedo project was subject to two different impact assessments – first during the preliminary project phase and then after the design was concluded.

This second procedure was carried out in order to check if all the project design amendments, mitigation procedures and other environmental issues identified by the official agencies responsible for the first assessment, were all correctly considered in the final design. During these two phases, public participation took place and all relevant contributions from NGOs, local authorities and the general public were integrated into the project.

The impact assessment studies allowed the environmental characterization of the project site, namely demonstrating its relevant conservation status – presence of important fish species (Trout), as well as birds (White-throated Dipper) and mammals (Pyrenean Desman), all of them with a high conservation status not only in Portugal, but also from a global perspective. The riparian and surrounding vegetation is also rich and diverse, with oak forest typical of Northern (Atlantic) Portugal present. The water quality is also characterized as being very good, according to the parameters of the Water Framework Directive.

The main initiatives to deal with the environmental relevance of the site involved the active implementation of mitigation measures, such as the design and construction of a fish passage to allow the



Construction of the dam. View of the block interface

Construction of the powerhouse

Fish passage in operation

natural movements of fish upstream. This environmental approach was combined with the study of an ecological stream flow regime that enables the preservation of the species, habitats and ecological characteristics downstream.

Attention was also paid to archeological and ethnographic values in the affected area and measures were carried out in order to preserve and study those heritage sites.

Another important feature concerned the compensation of the riparian habitat (namely by planting Black Alder, Grey Willow and Birch) by the lotic margins and the surrounding habitat, by protecting and planting oak trees (Quercus robur and Quercus pyrenaica).

Another essential phase of the environmental program is monitoring, particularly with regards to the water quality, flora and vegetation, fish fauna, riparian fauna (amphibians, reptiles, birds and mammals), and with special emphasis on White-throated Dipper, Otter and Pyrenean Desman. This program comprises monitoring the construction and exploitation phases of the Canedo plant, allowing systematic checking of the observed in situ conditions, as well as rapid implementation of amendment measures if necessary.

All these monitoring schemes are being carried out and the results obtained so far are consistent with the environmental feasibility studies of the project.

Operation phase

The power plant is fully automated and remote controlled from a dispatch centre. It is also equipped with an independent GSM remote alarm system.

The variations of the incoming water flow are evaluated daily by the dispatch centre, which is responsible for the settings adjustment. Parameters such as the operation of the previous day, the actual water level and the storage capacity of the dam are processed to establish updated parameters, which will achieve best efficiency from the generating set. The storage capacity of the dam is fully utilised to take advantage of the more valuable daytime tariff, thus increasing revenue. The aim is to have full storage capacity in the morning and minimum water level in the evening.

Despite being fully automated, the power plant is not unmanned. There is an operator on a full daytime basis.

There are daily and weekly routine maintenance schedules and also periodical and annual maintenance schedules. These schedules were developed in accordance with the maintenance schedules of the equipment manufacturers and also in accordance with RPG experience.

Equipment is thoroughly maintained and kept as original. With these procedures, availability is increased and outages are reduced. Weekly, monthly and annual operation reports are conducted, and specific reports would be issued if a failure situation occurs.

Project benefits

The Canedo project offers several benefits, both at regional and global levels. The major benefit is the average annual contribution of 28GWh of clean electricity for the national and European targets, avoiding 16,500 ton of CO_2 emissions. Another important long-term benefit is the new road to the dam and the bridge, which has improved the local population's mobility by connecting the villages of Vilar and Codeçoso. In addition, RPG provided a financial contribution, which was used by the municipalities for new social equipment.

Part of the civil construction was carried out by a local workforce, contributing to the regional economy. The dam's reservoir provides other significant advantages, including acting as a water reserve to fight forest fires and for recreational purposes such as fishing. The dam regulating capability also allows for greater stability in the summer irrigation flow. IWP&DC

For further information on the project, please visit www.rp-global.com or www.aqualogus.pt

Further photographs of the scheme can be found in the Canedo hydro project section on www.waterpowermagazine