BUILDING NAMIBIA'S LARGEST DAM

Upon completion, the Neckartal Dam will be the largest dam in Namibia, with a full supply volume of 853 Mm^3, exceeding the volume of the existing largest dam, Hardap Dam by a factor of nearly three. Projects of this magnitude need innovative construction technology in order to be executed successfully, Neckartal more so due to its desolate location in the arid climate of southern Namibia.

The dam is built in a deep valley, implying that the dam's surface area is relatively small for the volume of water held, making it ideally positioned to reduce the effect of evaporation in the dry climate experienced in Namibia. The Neckartal Dam reservoir will have a surface area of approximately 42 km^2, a perimeter of 295 km and full supply volume of 853 Mm^3.

Once commissioned, the dam will contribute significantly to the sustainable economic development of the //Karas Region. The dam will yield water for irrigating farms for crop cultivation covering up to 1 960 ha during Phase 1 which may be extended up to 5 000 ha in the future, employing several hundred people in the process. Two turbines at the main dam will generate hydropower for the irrigation scheme, as demand requires.

The project consists of a 76,5 m-high roller compacted concrete (RCC) gravity arch main dam; a 10 m-high RCC abstraction weir (both with an uncontrolled Ogee crest); a 2,1 m^3/s pump station; a 9 km-long, 1,1 m diameter pipeline; and an HDPE-lined embankment balancing dam to hold some 90 000 m^3 of water.

Innovation to decrease construction time

Making use of a continuous uniform double curved shape (the Ogee spillway) for the dam spillway inherently posed some difficulties for construction. Innovation was required to decrease construction time while maintaining the accuracy of the profile, avoiding honeycombing and blowhole formation of the finished Ogee structure.

For the main dam, conventional construction methods (using sliding formwork or guide rails) needed a re-think in order to reduce the duration time to construct the Ogee crest. The construction of the crest was executed using controlled permeability formwork. This technique reduced the construction duration by a factor of more than two when compared to conventional construction techniques.

To aid the site engineers' supervision (developing, monitoring and quantifying different construction activities), unmanned aerial vehicles (UAVs) were introduced. UAVs were used to develop accurate three-dimensional models from their photographic surveys which also were used for construction progress monitoring of the project. In addition, accurate surveys, project monitoring, material quantity measurements, Building Information Modelling integration and the sharing of insights around the construction site, were carried out with the aid of the UAVs. The Project is one of the first dam construction projects in the SADC region to apply this technology.

Contributing to a decrease in construction time, an improved productivity in the site laboratory was achieved by concentrating materials testing on the final RCC product rather than the individual constituents. The RCC mix design sieve analysis envelopes were based on the required upper and lower limits of the specification for each particular material ingredient.

As a production and quality control measure, this new material sieve analysis and moisture content test procedure was developed in the laboratory to correlate between designed RCC and produced RCC. This new laboratory technique drastically reduced the testing time when compared to testing all the different aggregates, sieve analyses and moisture contents. In future projects, flakiness and elongation test methods may be incorporated into this testing procedure during RCC construction. This innovative procedure allowed a quick assessment of the final RCC product.

The total volume of concrete required to complete the

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construction of the Neckartal Dam was just over 1 000 000 m^3. Interestingly, only 65 kg of cement was used per cubic metre of concrete. This low volume of cement is one of the characteristics of using roller compacted concrete that makes it such an economically sound choice for the construction of a dam wall of this magnitude. At peak production, construction had taken place 24 hours a day, seven days a week.

Innovation

Two physical models of the dam wall structure were studied during the design stage of the dam. These models were constructed to scales of 1:60 and 1:120, with the latter model including the upstream topography. The initial aim was to investigate the hydraulic behaviour of the stepped RCC spillway and to determine the efficiency of the energy dissipation structures situated downstream.

The study revealed that, for the recommended design discharge (RDD) flood event, a sub-atmospheric pressure region occurred downstream of the spillway crest that was further accentuated for larger flows. These results were in contradiction with known literature which predicts hydrostatic pressure to be present during the RDD.

The physical models showed that the effect of three-dimensional flow, curvature of the dam wall and the asymmetric approach channel could not be neglected when designing the Ogee crested spillway. The results were subsequently integrated for the development of significant improvements to the spillway layout, as well as the energy dissipation structures.

Health & Safety

The Fish River has intermittent flow and, for many months in the year, maybe dry. In times of rainfall, the flow can increase dramatically, turning a once dry riverbed into a raging torrent of water. In order to address the associated flood risks, an early warning system was installed approximately 30 km upstream.

This system detects upstream flooding conditions and sends messages via SMS to site, providing sufficient time to allow for people and machinery to be evacuated from any working areas that may have been flooded. Concurrently, a schedule of safe evacuation and emergency drills had been adopted.

Emergency and evacuation plans are constantly updated to deal with the rapidly changing construction and site conditions. As the height of the dam wall continued to increase, so had the safety risks. About 1 000 hours were spent on health and safety training every month. International experts were brought to site to assist with specialised training in rope climbing and rigging. Awareness campaigns addressed the prominent health-related risks such as HIV/AIDS, STDs and tuberculosis. The isolation of the site also brought people in contact with dangerous animals such as snakes and scorpions as well as zoonosis.

Quantifiable time, cost and quality

Flow in the Fish River is seasonal with the wet season from December to May, in good years. As the contract was awarded later than envisaged, the contractor had to re programme its work compared to that originally tendered. Coffer dams had to be constructed at unplanned times to take account of the shifted river flow. Unfortunately, this increased the time for completion and the overall cost.

Nevertheless, throughout all the unplanned disruptions, stringent quality control was maintained, both by the Engineer and the

Contractor. Concrete batch records, cube test results, pre-concrete inspections and hydro mechanical installation inspections and the like, were well documented, easily obtainable and constantly archived for easy reference.

Managing risk

In such a remote area, risk management held a high priority throughout construction. Cross border and international deliveries had to be monitored closely to ensure correct arrival times. Material deliveries needed to be continual when construction was at full production.

The contractor built a small residential area nearby to accommodate all levels of workmen, including management. The possibility exists that this may be made available to the local community once the project is finished.

Treading lightly on the environment

The Neckartal Dam and abstraction weir is being constructed within the 650 km long Fish River that flows through the site, into the pristine Ai-Ais/Richtersveld Transfrontier Park and through the Fish River Canyon before entering the Orange River.

During construction, consideration was given to the protection of the freshwater resources such as the sensitive downstream aquatic environment. The design of the abstraction weir incorporates a fish ladder to ensure that the seasonal migratory patterns of fish are possible.

Due to the dryness of the landscape and the associated slow regeneration of the vegetation, it is implicit that any areas disturbed during the construction remain visible in the landscape for an extended period. The developed quarry was located behind dolerite outcrops and therefore hidden from view. An ESIA undertaken by Knight Piésold resulted in the discovery of a new *Gladiolus* species (plant) and ensured that consideration was given to the unique saline habitats and heritage objects that will eventually be drowned when the dam reservoir fills.

Corporate Social Investment

The Snyfontein community will greatly benefit from the construction of the dam. Through consultation with the Ministry of Agriculture, Water and Forestry, the /Hai-/Khaua Traditional Authority and the Snyfontein community, a workshop was held to discuss the specific needs of the community. The local community suggested a number of proposals for sustainable development initiatives. Knight Piésold and Salini-Impregilo, the contractor, agreed to assist the community with three endeavours: supplying a brick factory, construction of a community centre; and fencing of the Snyfontein graveyard. Knight Piésold were to supply engineering services and the contractor would provide construction materials and concrete while the community would undertake the construction. Additionally, a donation of blankets was given to the Snyfontein community during the winter of 2016 and there is an intention that 200 erven will be supplied with services in Keetmanshoop. Eventually, the power supply to the project will be extended to Snyfontein and connect the community to the national electrical grid. ■

PROJECT INFORMATION

- **Client: Ministry of Agriculture, Water and Forestry (Namibia)**
- **Project value: N$4-billion**
- **Start date: September 2013**
- **End date: Expected mid-2019**
- **Main Contractor: Salini Impregilo**
- **Principal Agent: Knight Piésold Consulting**
- **Project Manager: Knight Piésold Consulting**
- **Consulting Engineer: Knight Piésold Consulting**