Into the Panama rainforest

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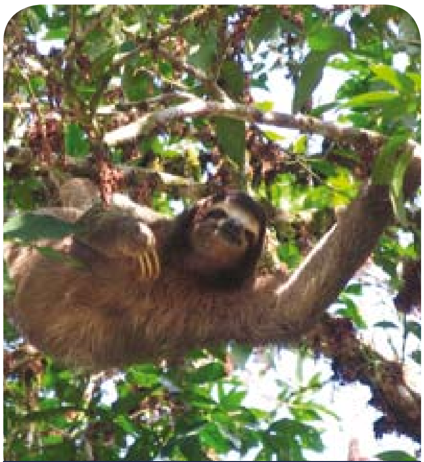
Building a dam for a large hydroelectric plant is in itself a very interesting project. When such a project is located in the rainforest in a remote area with a very limited infrastructure, the supply of cement and fly ash becomes quite a challenge, requiring a complete and dedicated import operation.

Overview of the Changuinola River, Panama.
See ICR June 2010 for further information concerning the installation of the Van Aalst shipunloader for this project

The construction of the Changuinola 1 hydroelectric project in the Bocas del Toro province of Panama requires over 250,000t of cement and fly ash. The remote location combined with a limited infrastructure provided unique challenges for transporting such a large quantity of cement and fly ash to the project site. The only workable solution was to bring the cement and fly ash to the project by sea. To achieve this a complete supply chain had to be set up involving overseas sourcing of cement and fly ash, sea transportation, the construction of a complete terminal facility and trucking of the cement and fly ash from the terminal to the storage facility at the site. In the first phase of the project the cement and fly ash had to be transported in big bags. This is a very comprehensive supply system and a highly interesting one as well! This article offers a description of the project, an insight into the complicated logistics behind it and how these logistics resulted in the solutions for the complete cement and fly ash supply chain.

Some of the residents of the Panama rainforest .... a capuchin monkey

...a red eye frog



...and a sloth

Description of the project

The Changuinola 1 hydroelectric project consists of the following five objectives:
1) a large dam in the Changuinola River with a height of over 100m and a width at its crown of over 600m. The dam will be built of Roller Compacted Concrete (RCC) and about 900,000m^3 of RCC is required
2) a tunnel with a length of over 4km and a diameter of 10m. The tunnel cuts off a bend in the river and in this way adds about 40m of water column to the water height of the lake behind the dam. The tunnel is blasted through the rock of the hills
3) a powerhouse with two turbines with a total generating power of 207MW located at the lower end of the tunnel. The turbine hall is about 10 floors high
4) a 9MW 'mini hydro' power plant at the dam which keeps an ecological water flow in the original riverbed
5) about 20km of permanent roads to the dam and the powerhouse, including four bridges and numerous ducts and culverts (plus about 8km of temporary roads). A large part of these roads has to be cut into hillsides with substantial improvements required to the hillside above.

To realise these key aims substantial temporary works are required including:

- a large concrete plant for the dam construction with a capacity of 650m^3/h and a 2000tph delivery system to the dam
- an aggregate mining operation in the riverbed over a length of about 3km. Over 2.5Mt will be mined
- a crushing plant with a capacity of 50,000t per week
- aggregate storage area of over 1Mt partly-covered
- a 8000kW diesel-driven power plant
- a large workshop servicing all plants as well as over 300 construction machines, trucks and cars, and providing construction work for the temporary works
- a batching plant for ordinary concrete and a small plant for shotcrete
- a large laboratory for constant quality control
- two housing camps: one for domestic labour of other provinces and one for expatriates and their families. These camps include water, sewage and electrical

infrastructure, recreational facilities, school and kindergarten, shop, etc.

• and of course a complete cement and fly ash import facility in the port of Almirante, consisting of a floating terminal of 23,000t, a floating pipeline and shore based truck loading silos.

The overall project has a value of over US$400m of which US$300m is for the civil works. The civil work has been contracted by Changuinola Civil Works JV, a combination of two large Danish contractors: E Pihl & Son and MT Højgaard. About 2000 people are currently involved in the civil works construction. The project started in 2007 and is scheduled for completion by mid-2011. At the end of November 2009 the concrete placement of the dam commenced.

Roller compacted concrete

The dam will be built of RCC mass concrete without rebar. To build a dam of the size of the Changuinola project about a full year of round-the-clock RCC placement is required. Due to the very large quantities involved the heat of hydration is a key factor in the mixture design. Therefore, the ratio of fly ash in the binder is very high. For this specific dam a binder mixture of about two thirds fly ash and one thirds of cement is used per cubic metre of RCC. The water content is kept as low as possible. Also a fairly high amount of retarder is used to extend the workability of the RCC. This is to prevent cold joints during the stoppages because of placing formwork, rain and other interruptions.

The RCC is transported from the plant to the dam by a conveying belt with a peak capacity of 2000tph. The conveyor belt has two large bridges at the end that can adapt to the raising level of the dam construction. From the belt the RCC is dropped into articulated off-road trucks that take the RCC to the pouring position and dump it there. The RCC is then spread out by laser-guided bulldozers and is compacted by heavy vibrating rollers.

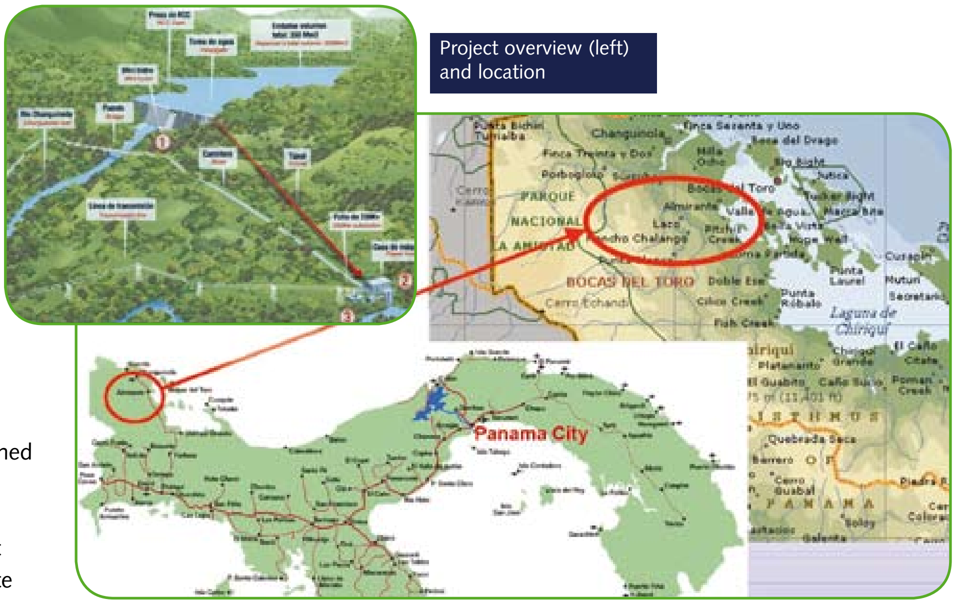
Complicated logistics

The logistics of this project are determined by the following factors:

Overall quantities: when the project started, the rough quantities of concrete were known but not the concrete recipes and required amount of binder. A total amount of about 240-260,000t of cement and fly ash was taken into account but with a large possible fluctuation between the two materials. In the first two years a large number of possible recipes were tested and with the progress of the design the quantities over time became more clear. During the set-up of the whole supply system, however, it was important to keep the flexibility to accommodate the wider possible ranges of material volumes.

Usage fluctuations: the total quantities of cement and fly ash are not equally divided over the construction period of the project. The overall duration of the civil works is about four years. In the first two years, the main work is earthmoving. Millions and millions of tonnes of rock and soil have to be cleared and moved to create roads and the construction areas. Concrete is then only required in relatively small quantities for culverts under roads, supports for temporary bridges, slabs for construction equipment, etc. After one-and-a-half years the first concrete batching plant starts and cement consumption begins to increase but still with relatively low volumes. In the last two years of the project a relatively large amount of regular concrete is produced for powerhouse construction, tunnel linings, bridges, etc, consuming about 60,000t of (mainly) cement and fly ash. The dam however demands almost 200,000t in a single year of construction. And this is not constant. There can be months where 5000t of cementitious materials are used and months where 30,000t is used! This depends on weather (tropical rain climate), construction phases, etc. Daily peak consumption can exceed 2000t of cementitious materials. To keep to the project schedule, it is vital that when circumstances demand peak production can be met. If this cannot be done the average production figure drops dramatically. The logistics of the cement and fly ash supply have to meet this peak demand.

Infrastructure limitations: the project is located in the middle of a tropical rainforest in a sparsely-populated and very poor province of Panama, close to the border with Costa Rica. There is only one two-lane road that connects the province with the rest of Panama and this road has to go through a mountain pass at 1500m height. During the 2008 rainy season the road became damaged in 83 places and was out of operation for over three weeks. It continues through the province into Costa Rica but the border crossing is a 100-year old single-line railroad bridge which trucks and cars have to pass, driving on wooden planks beside the rails. For a bulk truck to pick up a cargo of cement at the nearest cement plant and return to the project is a trip of three days. Transportation by sea was an obvious requirement. Also fly ash, the key requirement for the dam, is not available in Central America, making overseas sourcing a necessity. The project is located about 18km from a small port, Almirante, almost solely used for banana exports. This port has two old docks which were unable



Project overview (left) and location

Overview of dam construction (top left), concrete placement on dam (above) and RCC plant (left)

to support a heavy shipunloader (see ICR June 2010). Also, most port space was occupied by refrigerated container storage with insufficient room for a temporary import facility. However, Almirante is located in a very sheltered bay with deep water very close to shore. This opened up the possibility for a floating terminal with a floating pipeline to shore and shore-based truck loading silos.

Sourcing of cement and fly ash

The initial focus was finding a source for fly ash as cement was considered more widely available with the best possibility turning out to be the USA. In terms of cement supply a much wider range was initially considered but given limitations regarding draught, freight costs (this was before the financial crisis) and the cost of the temporary import facility the sourcing of cement was soon limited to the Caribbean/Gulf of Mexico range. The required consistent quality levels of cement and fly ash are an important factor in the mix design and influence the required material volumes.

As so many factors were still undetermined at the start of the project the only way to work was to build a logistic and economic model of the whole supply chain and use several scenarios to determine the consequences for each part. As the basis the concrete production schedule for the project was taken and separate but interconnected spreadsheet pages were made for supply, shipping, floating terminal, shore-based truck loading unit, trucking and storage facilities on site. The model calculates all logistical aspects as well as operating and capital expenditures. Working in this way has several advantages. Firstly, all variables and how they are interlinked becomes clear. This gives a good insight in the whole supply chain and what the key factors are. Secondly, by changing production schedules and concrete mixes on one side and ship size and shipping schedule on the other side, the model clearly shows the corresponding requirements of the overall terminal facility in Almirante, the number of trucks and the storage facilities at the project site. It also shows the costs of each scenario. Finally, when suppliers, size of floating terminal and other aspects become fixed the model clearly shows the possible variations of the undetermined other factors.

With the model as the basis, the solutions for the whole supply chain logistics were worked out. The following are the results.

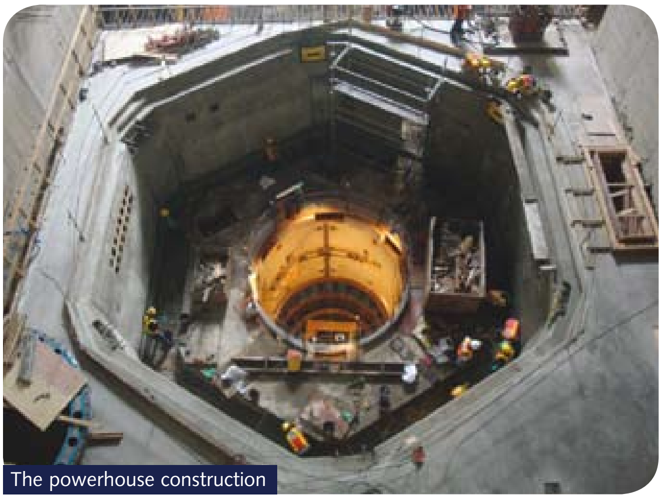
Cement and fly ash supply from the USA

Cement for the project is supplied by Titan America. The fly ash is largely from its subsidiary Separation Technologies, and manufactured at its new production unit at the Big Bend power station in Apollo Beach, Florida. The electrostatic separation of the fly ash in combination with a constant quality control process produces a consistent high quality. This not only enabled a high ratio of fly ash for the RCC concrete but also a relatively high ratio in the regular concrete. The plant has a maximum output of about 20,000t fly ash ('Pro-ash') per month. It has a storage silo of 10,000t at the facility. The fly ash is trucked from there to the port of Tampa. At Tampa, Titan America has a large cement import terminal. There, Separation Technologies stores the fly ash in one of the large silos which has a capacity of about 14,000t. During the year of the construction of the dam about 140,000t of fly ash will be shipped from Tampa. For a few peak months over 15,000t per month will be loaded into Changuinola Civil Works ships. In this respect the large buffer storage that Separation Technologies could offer is an important feature in the overall supply logistics. The cement is supplied from Titan Americas

Pennsuco plant, just north of Miami, Fl. This is a very modern plant (about four years old) with highly-automated quality control producing consistent high quality cements. Changuinola Civil Works is being built using Type I/II cement that this facility produces. This has a large logistical advantage as the project's technical specifications stated Type I cement for the dam and a Type II cement for the regular concrete. The plant has a capacity of about 2.7Mta with very large storage facilities for its final products. In this respect the large quantity of cement that Changuinola Civil Works is using in the year of the dam construction is no problem from a logistical point of view. The cement is trucked from the plant to Port Everglades and is conveyed directly from the bulk trucks into Changuinola Civil Works ships.

The use of big bags for the first phase

Building a bulk terminal (even a temporary one) takes time. In order to transport cement and fly ash during the first phase of the project a different method was required. Big bags proved to be a good solution for this although there definitely has been a learning process. To ship the fly ash and cement, general cargo ships with a cargo capacity between 2500 and 6000t have been used. Both for loading and discharge the ships' cranes were used. In the loading ports, Tampa and Port Everglades, most of the cargo was stored in port warehouses before the arrival of the vessel with only a small part of the cargo going directly from truck to ship. In the discharge port at Almirante, however, there was no storage space and all big bags were loaded directly from the ship to trucks and transported to the project site. Loading and discharge rates of 2000tpd were nearly always met. On average about 4000t were in store but in peak days, right after a ship discharge, up to 10,000t were stored. A simple big bag cutting and bulk truck loading system was developed, fed by a front-end loader with lifting beam. In a two-shift operation about 200tpd could be transferred from big bags to bulk trucks. The big bag operation was initially foreseen to be used only for about half a year and with relatively low throughputs. However, with delays in dam construction and the bulk import facility, it was required for more than a year and had to supply sizable quantities for the diversion culverts for the river, the powerhouse construction and the tunnel linings. Almost 40,000t of cement and fly ash were shipped and handled in big bags in the first phase.


The powerhouse construction


An Indian village close to the dam

Self-discharging ships

When shipping cement and fly ash there are two options that can be considered: regular bulk carriers or specialised self-discharging ships. Self-discharging ships have the disadvantage that they have to make an empty return trip and in this way are expensive. However, when used on short distances (the sailing time between Florida and Panama is about five days) this disadvantage disappears, especially as there are very little exports from Panama and nearby countries other than specialised fruit shipments. Self-discharging ships have a much higher efficiency in loading and discharge and can discharge under all weather conditions (which is a serious consideration in a tropical rain climate). For this project the use of self-discharging ships had the additional advantage that larger vessels could be used. The floating terminal in Almirante has a shipunloader to discharge itself. It is also able to unload regular cargo vessels alongside the floating terminal as long as these have a maximum cargo capacity of about 6500t. With self-discharging ships there was no such limitation, which made the market range for these vessels greater and operating costs for these larger vessels lower. Self-discharging ships have a higher time-charter rate but for this project their higher efficiency made the best option both from economic and operational viewpoints. Two self-discharging ships were taken into time charter for this project. The UBC Cork collected its first cargo of fly-ash on November 22, 2009 in Tampa and

Cement loading in Port Everglades (above), floating terminal in Almirante (right)

the UBC Cartagena arrived in February 2010. Both vessels were chartered from United Bulk Carriers which is a division of Intership Navigation in Cyprus. The broker for both time charters was R G Jones Price. The vessels are brand new and came directly from the shipyard in China. They have a cargo capacity of about 7800t. The vessels have each been fitted with 14 truckloading connections and in this way can be loaded at about 4000tpd. The vessels are fitted with a 600tph MacGregor (formerly Nordströms) mechanical/pneumatic discharge system from Cargotec Sweden, Marine Selfunloaders business line.

The terminal in Almirante

The supply of cement and fly ash by sea to the project is possible because of the vicinity of a small port relatively close to the project. The port of Almirante is basically a banana export facility operated by Chiquita. Although the port has been maintained and upgraded over the years, its two docks were built a century ago and have weight restrictions. The docks had to be fully clear for the refrigerated container operations so no permanent equipment on the dock was possible and mobile equipment would be too heavy. Also the banana ships would always have priority. Moreover, the large container yard at the port made a sizable storage facility for cement and fly ash within suitable distance from the docks impossible.

However, the port offered the basic infrastructure and services to bring in the cement and fly ash vessels: a buoyed navigation channel with a depth of 11m, pilots, customs and immigration, agent services and security. The road system supporting the banana container traffic is relatively good. Moreover, the port is located in a very sheltered bay which in turn is protected by a row of islands. Wave height does not exceed 0.5m and the port is outside historical hurricane reach.

The bay has also good water depths continuing quite close to shore. This made it possible to put a floating terminal at about 100m from shore and run a floating pipeline to shore-based truck loading silos. The number of floating terminals in the world is quite small (less than 50). Availability of the right size and type of floating terminal was basically zero and time chartering costs would have been prohibitive especially as this was before the financial crisis. A decision was made to convert an old regular bulk carrier into a floating terminal. This was still during a time when shipping prices where about 2.5 times current levels and so very few vessels were available for sale. Practically the only option was an old hull of a Great Lakes bulk carrier in Canada dating back to 1961.

However, the vessel turned out to be in quite acceptable condition. There was little corrosion as the vessel had only been used in fresh water environment. It was also built for ice navigation and still had substantial plate thicknesses. The aft part of the vessel with machine room and deckhouse had been cut off in 1998 and after that the remaining hull was used as a floating grain storage on the Saint Lawrence Seaway close to Montreal.

The vessel was purchased by Changuinola Civil Works and delivered by the previous owner at the port of Limon in Costa Rica. Whilst being at anchor the vessel was converted into a floating terminal by Costa Rican subcontractor Estrumet Metallurgica SA under direct supervision from Changuinola Civil Works JV. With hindsight, this has been a major undertaking in which over 250t of steel, piping and equipment were put on board. The hull, above water level, was sandblasted and painted. The watertight divisions of holds and other compartments were restored. About 500m of cement and fly ash conveying piping was put on board as well as fuel, water and waste water systems. A gantry to support the shipunloading system was built and a lot of existing equipment on board was overhauled.

The shipunloading system is a 200tph pneumatic system supplied by Van Aalst Bulk Handling. The pneumatic unloader was delivered in containerised elements, allowing easy transportation. During its conversion period the floating terminal 'Laviolетta' has only been to the dock twice. Once to load the shipunloader elements, generator set, dustcollectors, etc and the second time to lift the heavy spudpoles on board that keep the floating terminal in position. Apart from these

Floating pipeline to silos (above), floating terminal (above right), pneumatic discharge of floating terminal (far right), Indian canoe close to floating terminal (right)

two visits the whole conversion was made at anchor. 'Laviolettа' has a storage capacity of 23,000t divided over five holds. In empty condition her draught is about 2.5m. Fully-loaded, her draught is about 8.8m. With a length of 150m, a width of 23m and a depth of 12m she is the largest vessel in Almirante and quite a presence there. In September 2009, she was towed from Limon to Almirante and put into her operating position. By lowering the spudpoles of the vessel she has been firmly fixed into position.

A floating pipeline of about 120m connects the floating terminal with the shore-based silos. Floating pipelines are not common for cement and fly ash conveying as forces on them can be quite high when they are too rigid and conveying resistance will be too high when the pipeline is very flexible. The sheltered area and low wave height made it possible to provide a solution that maintains a low conveying resistance but provides sufficient flexibility to cope with waves, tides and the changing draft of the floating terminal.

The floating pipeline consists of two sections of about 60m length fitted on floats connected to each other, to shore and to the floating terminal by multilayered wear-resistant rubber hoses with steel reinforcement. On top of the floating pipeline there are fuel, water and waste water lines as well as a conduit for electrical cables.

The shore-based silos are located in a more remote area of the port. The maximum conveying distance taking into account the pipelines on the floating terminal, floating pipeline and shore pipelines is about 380m. The silos are bolted and of the drive-through type. Bulk trucks are loaded underneath the silos whilst standing on the truck scale. The silos have been supplied by Columbian TecTank. The fly ash silo has a capacity of 1000t and the cement silo is 800t. They are fitted with DCL truckloading equipment and Donaldson Dalamatic dust collectors. Extensive piling and foundations, earth works, erection and supervision for the shore-based silo facility have been provided by Changuinola Civil Works JV itself.

Transportation to the project site

The transportation to the project site is done by Changuinola Civil Works JV itself. As part of its large fleet of construction equipment it has 15 Freightliner 6x4 tractor trucks that provide a wide range of transportation services. They are used with container trailers, flatbed trailers, lowbed trailers, kipper trailers and bulk trailers.

The 10 bulk trailers for cement and fly ash are supplied by Romarco from Colombia and have a capacity of 30t. Using all bulk trailers a peak transportation capacity of 2000tpd between Almirante and the project site can be achieved. The bulk trailers do not have their own compressors. High-capacity compressors for the bulk truck discharge are located at the silos of the large RCC plant, and the plants for regular concrete and shotcrete.

Silo facility at the RCC plant

The silo facility at the RCC plant consists of two large storage silos and eight day silos. The storage silos consist of a 1800t fly ash silo and a 1000t cement silo. The RCC plant has four mixers that each have their own day silo for cement and fly ash. The overall combined storage capacity of the plant for cement and fly ash is about 4000t.

... a job well done

On peak production days the RCC plant will consume over 1800t of cement and fly ash (together with over 20,000t of sand and aggregate). The large storage silos have been supplied by Columbia TecTank and the dust collectors by Donaldson Dalamatic. Three pneumatic conveyors (50tph each), supplied by Cyclonaire, provide the conveying from the large silos to the day silos. Foundations, erection and installation of the whole plant including all silos and related equipment have been done by Changuinola Civil Works JV itself.

Conclusion

I hope that this article has given an impression on what is needed to supply a large volume of cement and fly ash to a remote location in the rainforest in Panama. It is somewhat amazing to realise such an extensive supply chain for such a short period of time. Then again, it is only a small part compared to the overall temporary works and equipment needed to realise this large project. Overseas cement and fly ash supplies, a big bag operation, self-discharging ships, a complete import facility including a floating terminal, floating pipeline and shore-based truckloading silos, a fleet of bulk trucks and a large silo facility at the project site were all realised to bring in 260,000t.

"Almost within one [helicopter] view, it is possible to see the cement and fly ash arriving in Almirante and the dam going up at the Changuinola river with a beehive of activity in between."

With the possibility of other major projects in the area there is a chance that the terminal facility will stay in Almirante for several more years.

Then again, this might not happen in the near future and all equipment including floating terminal and silos will then be relocated to other projects over the world. The floating terminal with is spud poles and floating pipelines can be used to establish an import facility almost anywhere at very short notice even in very remote locations. Meanwhile, this makes a fascinating project! Almost within one (helicopter) view it is possible to see the cement and fly ash arriving in Almirante and the dam going up at the Changuinola river with a beehive of activity in between. It is a showcase for specialist construction, sophisticated concrete mixtures and comprehensive logistics to get the building materials to site.

Trucking to project site (right and below right) and truck discharge in RCC plant silos (below)