6TH INTERNATIONAL SYMPOSIUM ON
ROLLER COMPACTED CONCRETE (RCC) DAMS
Zaragoza, 23 – 25 October 2012

A UNIQUE CEMENT AND FLY ASH SUPPLY SYSTEM FOR THE CHANGUINOLA I PROJECT IN PANAMA

Ad LIGTHART
Partner, Cement Distribution Consultants, The Netherlands

Chris HICKS
Principal, Krow LLC, USA

SUMMARY

This paper describes the unique cement and fly ash supply system for the Changuinola I hydro electrical project located in Panama. By using a floating terminal, designed to operate independently from any port facility and only requiring a sheltered berth, the contractor created the possibility to import cement and fly ash by sea. This not only overcame the road infrastructure limitations to supply the project but also allowed to source cement and fly ash more economically and from a much larger region offering more options and competitiveness.

A seaborne supply system for cement and fly ash is fairly complex. This paper describes the complete logistical system and all the factors that have to be taken into account when setting up such a system. Part of this description is the floating terminal itself as well as the two self-discharging ships that provided the sea transportation of the cement and fly ash.

1. INTRODUCTION

The Changuinola I project consists of a large RCC dam, a 4 km tunnel, a 205 mW main power house and a 9 mW mini hydro plant and is located in a very remote area in north western Panama. The contractor “Changuinola Civil Works J.V. Inc.” (a J.V. between E. Pihl & Son and MT Hojgaard) initially considered natural pozzolan sources as no suitable fly ash supply was available in Central America. The natural pozzolan sources, after investigation by the contractor were not as suitable for the RCC mix design as hoped. Also the level of effort, timeframe for design and construction and capital cost of a grinding plant for natural pozzolan was unattractive. This meant that an overseas fly ash supply was required.

In respect to cement plants, there were two in Panama and one in Costa Rica, but both with a single road connecting them to the project. Many sections of the connecting roads in both Panama and Costa Rica were in poor condition and vulnerable to flooding and landslides. A round trip for a bulk truck to pick up a cargo of cement at one of the cement plants in the Panama Canal Zone took three days. As such, sea transportation was the only realistic alternative.

Fig. 1
Project location

Fig. 2
Poor road infrastructure

Located approximately 18 km from the project is the small port of Almirante, mainly used for the exportation of bananas. The dock facilities and available storage space were not adequate for a cement and fly ash import terminal but the port did offer a deep water (11 meters) access channel, a sheltered berthing area, as well as pilot services, shipping agent, customs, and immigration facilities. With the port of Almirante as the basis, a complete seaborne cement and fly ash supply system was conceptualised.

2. LOGISTICAL REQUIREMENTS

In the beginning of the project there were still many unknown factors and variables. The design for the dam was still in progress, the RCC mixture proportions were not yet determined and the project schedule was still very dynamic, and there were only preliminary estimates to work from. Early in the project these estimates were for a total of 240.000 – 260.000 tons of cementitious material (cement and fly ash) to be needed, split between 55.000 – 60.000 tons for the production of conventional concrete and 185.000 – 200.000 tons for the RCC in the dam. Before the start of the RCC placement, approximately 40.000 tons of cement and fly ash would be required for the various civil works and full scale RCC testing over a period of approximately 20 months. After that approximately 200.000 to 220.000 tons of cement and fly ash would be required over a period of approximately 16 months to build the dam and the remaining civil work.

When a seaborne supply of cement and fly ash is used the logistics become fairy complicated. This is illustrated in the flow sheet below.

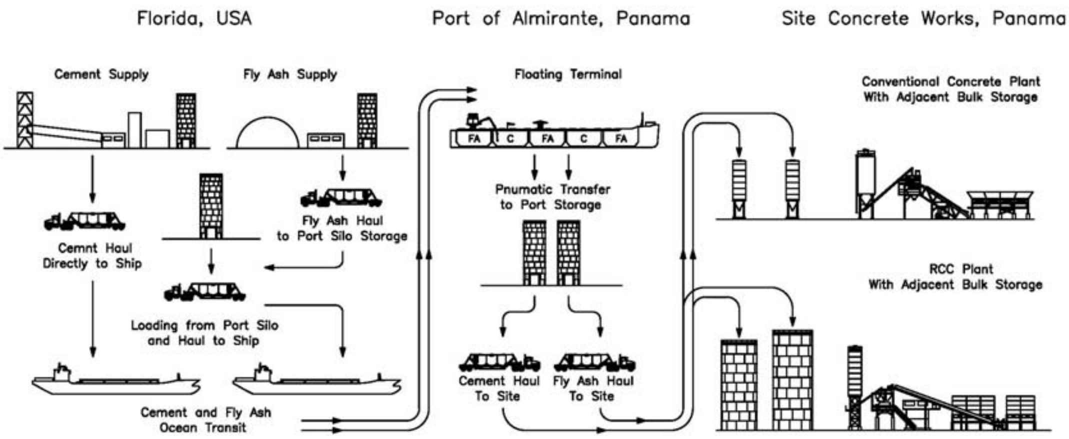


Fig. 3
Flow Sheet

The logistical system consists of:

- Production capabilities at cement and fly ash plants
- Buffer storage at the plants
- Road transport between plants and port
- Buffer storage in the port
- Road transport from port buffer storage to the ship and loading the vessel
- Sea voyage
- Discharge of the vessel in Almirante
- Buffer storage in Almirante
- Movement from buffer storage to truck loading silos in Almirante
- Road transport from Almirante to project site
- Buffer storage at concrete plants

The key factor in the logistical system was the shipping distance, as this determined the economical size of ship to use. The ship size in turn determined the required storage volumes in the loading and discharge ports, as well as the required loading and discharge capacities. However, early in the project the cement and fly ash suppliers had not yet been determined, although the permit application process for the import facility had to be started immediately to be in place for the construction of the dam and not cause a delay.

For a seagoing distribution system no easy “rule of the thumb” formulas are applicable. What was created was a very involved spreadsheet business model of the entire logistical system with interlinked pages for each separate step. These pages calculated the logistical factors, production requirements and adjustments as required, as well as the capital and operating costs. The spreadsheet started with the scheduled production (and with that the cement and fly ash consumption) and then back calculated though the logistical system checking if every component met the project schedule requirements and projecting the related costs of each solution. Such a business model allowed for the use of various scenarios to evaluate what their impact would be on the logistical system as a whole. As mentioned, there were still many factors unclear in the beginning of the project but some early decisions were needed in respect to the environmental permit application for the Almirante import facility. Using the business model, good knowledge on seaborne cement distribution systems, and other assumptions the following decisions were taken.

- The cement and fly ash suppliers would have to be found within the Gulf of Mexico – Caribbean area to keep the economical ship size and import terminal cost within a reasonable ratio. This meant that depending on the actual shipping distance the most economical ship size would be between 4.000 tons and 8.000 tons of cargo capacity.
- As the port facilities of Almirante were limited in terms of available support of a shore based storage and unloading facility, a floating terminal would be used. Based on the business model the floating terminal would need to have a storage capacity of minimal 25.000 tons to receive both cement and fly ash from vessels of 8.000 tons cargo capacity.

3. SOURCING CEMENT AND FLY ASH

The fly ash supply situation was fairly straightforward. Natural pozzolan sources had been ruled out and no suitable fly ash was available in the Central America and Caribbean area. However in the USA Gulf of Mexico region there were two large suppliers with multiple production facilities with sufficient non-utilized production capacity for the project. After a technical and logistical comparison and the commercial bidding process a supplier from Florida was selected. The fly ash would be supplied from their production unit at the Big Bend Power plant in Apollo Beach in Florida and would load the ships in the Port of Tampa. This production unit was able to produce 20.000 tons per month and had a finished product silo of 10.000 tons capacity. As the peak demand of the project was 20.000 tons of fly ash per month and it would be possible that two ships could arrive for loading within days of each other, some very well defined logistical arrangements had to be made. During the peak months of the project the fly ash supplier would supply their Florida customers from their production unit located in Jacksonville and would use their Big Bend production facility solely for the Panama project. In the Port of Tampa a silo of 14.000 tons capacity could be used as an export facility. The port silo was supplied on a regular daily basis by bulk trucks.

When a ship came in to be loaded a total of up to 8 bulk trucks were used to transport the fly ash from the port silo to the dock and then into the ship.

Fig. 4
Tampa fly ash export facility

Fig. 5
Cement plant, north of Miami

The cement situation was more difficult to evaluate and to determine an optimal solution. In Panama there were two cement suppliers, the economy of Panama was strong, and both suppliers were expanding their plants during this expansion and cement shortage situation occurred, raising ex. Works prices by approximately 40%. The nationalization of the cement industry in Venezuela further complicated the issue, as a large supply base to the Caribbean area fell away.

The financial and economic crisis of 2008 opened up new possibilities, and changed the scene dramatically. The Florida cement market shrunk by approximately 50% and instead of importing approximately 5 million tons of cement per year, the state now had surplus capacity. Discussions started with a Florida cement supplier and were also completed by the end of 2008. The cement supply was made from their plant, north of Miami and the ships were loaded in Port Everglades approximately 24 km away. This plant had over 70.000 tons of finished product silo storage and an annual production capacity of 2,7 million tons, more than adequate to supply the project. However, to reach the guaranteed ship loading rate of 4.000 tons per day a fleet of 25 bulk trucks had to be mobilized. As neither supplier had any experience with exporting by ship, most of the logistics had to be arranged in detail between supplier and contractor, with the logistical requirements included in the supply agreements. In these agreements the following issues were covered:

Table 1
Issues covered in cement and fly ash supply contracts

• Quality specifications • Quantity definitions o Guaranteed minimum o Possible maximum o Penalties for non-performance • Price o Basic price o Escalation over time o Payment conditions o Financial guarantees • Delivery conditions o F.O.B. Incoterms 2000 o Definition receiving capability of ships ▪ Loading connections ▪ Dust collector capacity ▪ Guaranteed loading rate ▪ Penalties for non-performance	• Supply obligation o Definition of supply source o Plan B o Keeping sufficient stock ▪ Max. ship size ▪ Minimum interval between ships ▪ Max possible deviation from schedule • Scheduling o Rolling schedule updated monthly and after big changes o Ordering procedures o Notification obligations • Use of general port facility o Obligations of supplier to fix dock availability o Options when dock is not available and corresponding responsibilities • Remedies, Force Majeure, Termination, other General conditions

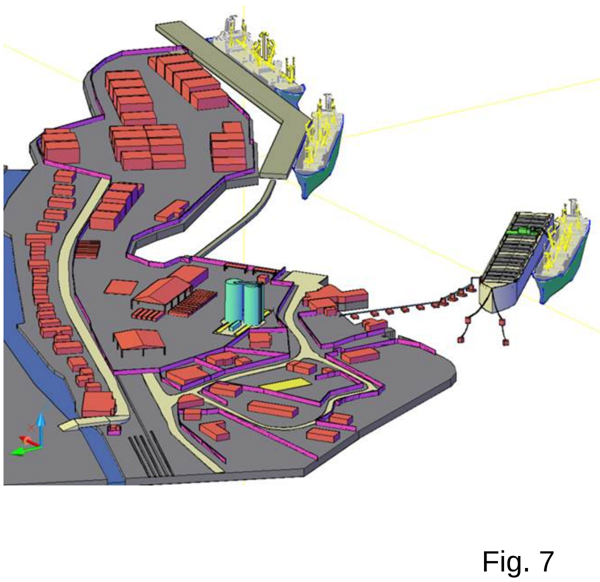
4. THE TERMINAL FACILITY IN ALMIRANTE

Based on the use of ships with a maximum cargo capacity of 8.000 tons, required storage capacity for both cement and fly ash considering peak RCC placement requirements was determined to be 25.000 tons. Given the limitations of the port facilities, a floating terminal was determined to be required. There are only approximately 30 floating cement terminals in operation in the world. Very few of those met the project requirements and most of these vessels are owned or controlled by individual cement suppliers. The decision was taken to build a floating terminal that would meet the specific requirements of the project but would also be suitable as a general floating cement terminal so it could be sold after the project. A used barge with a cargo capacity of 23.000 tons was found in Canada. It was built as a Great Lakes bulk carrier, which are long vessels with a narrow width to fit in the locks of the waterway system bordering the USA and Canada. In 1997 the machine room section along with the deckhouse had been cut off to be re-used on another vessel. By fitting a new transom and ballast system the remaining 5 holds of the vessel and the bow were transformed into a barge. Between 1997 and 2008 the vessel had been used as a grain storage barge moored close to Quebec. The vessel was quite old (built in 1961) but as it had spent its whole life in fresh water the condition of the hull was quite good. The vessel had been built for sailing in ice conditions and was fitted with a double hull and box type holds. The longitudinal strength was still sufficient that as a floating terminal she could have one hold empty and the other adjacent holds full. As a result, the barge actually was very suitable for conversion to a floating terminal.

Floating terminal Laviolettta
Storage capacity 23.000 tons
5 Holds

Length	151,3 m
Width	22,9 m
Depth	11,0 m
Draft	8,6 m

Fig. 6
Floating terminal Laviolettta with specifications



Conversion Work

- Repairs and modifications to hold structure
- Product conveying pipelines, fuel, water and waste water pipelines
- Refurbishment ballast system
- New gantry for ship unloader
- Installation of ship unloader
- Installation of generator set
- Installation of spud poles
- Electrical installation

Fig. 7
3D CAD model of the Laviolettta position in Almirante Port

The Laviolettta was converted and re-fitted in the Port of Limon, Costa Rica, about 3 hours from the project with CCWJV as main contractor and local subcontractors. The barge was fitted with a pneumatic (vacuum-pressure type) unloader rated at 180 tph. This was more than sufficient to reach the peak project requirement of 1.800 tons of cement and fly ash per day. The unloader was built in container sized components which allowed for low transportation costs and erection with the limited crane capacity in Limon onto the floating terminal.

The Lavioletta was designed to be completely independent of any port facility. It is a combination of a floating dock (to berth the incoming ships with cement and fly ash) and a floating storage. The vessel was fitted with two spud poles of 22 meters length for anchorage. When both spud poles are lowered the vessel is secured firmly in position in water depths between 10-14 meters but can move up and down with the tide and changing cargo conditions. The pneumatic ship unloader is capable of conveying the cement and fly ash via a floating pipeline to the shore based truck loading silos. Via this floating pipeline structure, the vessel can also be provided with fuel, fresh water and (in an emergency) with electricity.

On shore, two truck loading silos (bolted type) were erected with a capacity of 1.000 tons for fly ash and 800 tons of cement, also meeting one peak day of RCC placement. The silos were of the high-rise type with trucks being loaded underneath the silos by gravity whilst parked on the truck scale. This allowed for loading times of 3 minutes for a 30 ton load.

For transportation to the project site up to 10 bulk trucks were available. At the RCC plant at the project site there was a 1.800 tons fly ash silo and a 1.000 tons cement silo as well as 8 day silos of 165 tons each. This meant that overall cement and fly ash storage capacity on and near the project was close to 29.000 tons.

Fig. 8
Pneumatic unloader

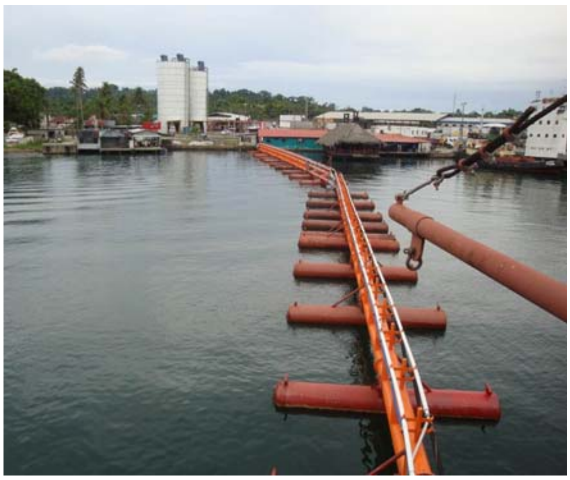


Fig. 9
Floating pipeline and silos

5. SELF DISCHARGING CEMENT CARRIERS

Given the sea distance between the two ports in Florida and the Port of Almirante two vessels with a cargo capacity of about 7.500 tons were required. Given the anticipated RCC placement schedule and the peak placement requirement one vessel would be required for the full duration of the dam construction and the second vessel for a period of about 8-9 months, starting 3 months after the first vessel. The business model of the logistical system had shown that using self-discharging cement carriers would result in better economic performance than the use of regular bulk carriers. Although the global fleet of self-discharging cement carriers was around 400 ships in the early days of the project the availability was still quite restricted as most vessels were on long-term time charters for domestic distribution or fixed trading routes. However the crisis in 2008 changed the situation completely and a good number of vessels became available at very acceptable charter rates. Using the business model a comparison was made between the various ships offered using the following factors.

- Actual cargo capacity (Deadweight minus anticipated fuel, fresh water and general stores)
- Fuel consumption (sailing under various conditions, daily generator use, cargo equipment during loading and discharge operations)
- Daily charter rated over the anticipated duration of the time charter period
- Loading and discharge capabilities
- Positioning issues (Duration of travel from the location of the ship to the project area)
- Hold volumes. As the majority of the material to be transported was fly ash, which requires about 25-30 per cent more volume than a cement cargo of the same weight, the hold volume of the ship was very important.

The vessels taken into time charter were the UBC Cork and (3 months later) the UBC Cartagena. Both were brand new vessels that came straight from the Manufactures' ship yard in China.

Fig. 10
UBC Cork

Fig. 11
UBC Cartagena

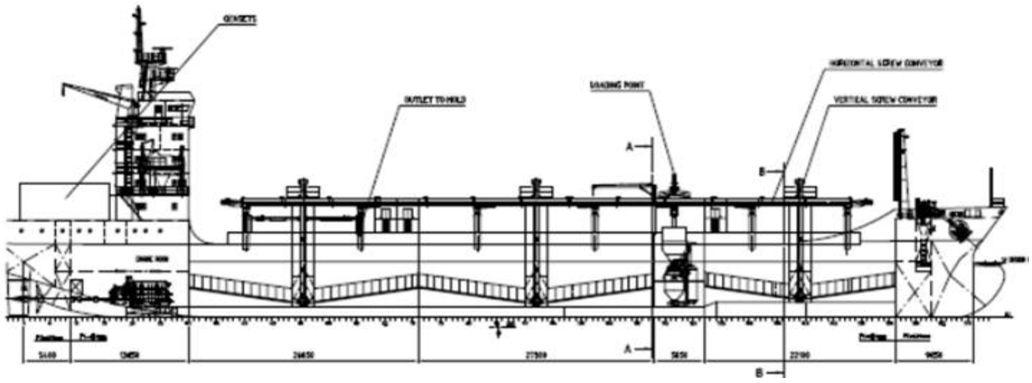


Fig. 12
Ship drawing

Table 2
Particulars self-discharging ships

Length oa: 117,00 m Breadth: 19,70 m Depth: 8,50 m Draft: 6,40 m Dwt: 8.600 resulting in a cargo capacity of 7.800 ton Cargo hold volume: 6.740 m^3 Fuel consumption Sailing: 19 mt/day IFO 380 at 14,5 kn. Generators: 1 mt/day MDO Discharge: 9 mt/day IFO 380 at 600 tph	Two main engines each driving propeller and a generator Discharge system: Nordströms Mechanical extraction from hold and pneumatic discharge to shore Capacity: 2 x 300 tph Dust collectors: 6 x 1.200 = 7.200 cbm/hr

When using a time charter agreement to charter a ship the ship owner provides the ship, the crew, crew provisions and maintenance. The charterer is responsible for the scheduling of the vessel, port arrangements and costs and bunkering (providing the vessel with fuel). A time charter agreement consists of a standard charter with a number of additional conditions.

Table 3
Charter party and additional conditions

Charter party	**ADDITIONAL CONDITIONS**
BIMCO uniform time charter (Baltime 1939, Rev. 2001) • Contract partners • Ship specifications • Fuel consumption • Charter period and possible extensions	• Loading conditions / capabilities (must match with supply contract and actual situation in port) • Discharge conditions / capabilities (must match with receiving terminal and actual

• Charter price / payment terms • Place of delivery and redelivery • Notification issues • Trading limits • Off hire situation • General conditions	situation in port) • Equipment availability definitions • Vessel to comply with US regulations! • Various issues regarding trading in the Caribbean

6. MANAGING OPERATIONS

For a project of this nature most of the preliminary effort of the cement and fly ash supply system goes into the preparations and the construction of the terminal facility. Then, approximately 7 weeks before the large scale RCC placing began the first ship commenced to fill up the floating terminal and the operational management started. Apart from the initial testing and adjustments, the operation management of a logistical system largely consists of coordination and scheduling. The activities are mentioned in table 4:

Table 4
Operation management activities

- Loading port arrangements (via agent)
    - Tugboat
    - Pilot
    - Dock
    - Documents
    - Customs
- Interaction between charter – Agent – Port – Supplier – Ship – Shipping co
- Fuel scheduling
    - Optimal quantities
    - Supplier situation
    - Price hedge possibilities
- Ship Charterer interaction
- Discharge port arrangements (same as loading port except for tug boat)
- Interaction Terminal – Ship
- Crew arrangements of floating terminal
- Security arrangements in the discharge port

A key feature of operation management is scheduling. As the shipping schedule was completely dependent on project progress and on-going related developments, a spreadsheet was set up with interactive pages covering all logistical and economical activities (concrete placement, trucking terminal operations, shipping, personnel, payments, etc.). Every day, the forecasted values were replaced by actual figures and the forecasts were recalculated.

Table 5
Inputs and outputs of calculation model

Inputs	Outputs
• Concrete placement forecasts • Trucks loaded at terminal • Silo and floating terminal hold levels • Silo levels at concrete plants • Terminal operating values • Ships positions and tank levels • Ship loading information • Payments	• Terminal operations scheduling • Ship scheduling • Stock situation • Internal invoicing • Cost overview and projections • Cost per tonne calculation • Cash flow projection • Day-to-day historical overview

Part of the operation management is also to look for operational cost savings. One aspect of that is of course to incrementally improve the operations of the terminal facility and the truck transportation system to the project site. Most cost savings however, can be realised on the shipping aspect. For every shipment the vessel was loaded to the very maximum. This means that bunker (fuel) levels have to be kept to a (safe) minimum. Cargo hold volume issues (for fly ash) also have to be addressed for every voyage. The captain of the ship takes the final decisions on these subjects but the charterer can influence these.

A large savings was made on fuel. By reducing the speed of the ship when the schedule allowed, the fuel cost savings per ton of transported cargo were as high as 40%. Part of cost saving was also to prevent delays in the loading ports where costs and demurrage could escalate quickly.

Fig. 13
Loading cement in Port Everglades

Fig. 14
Loading fly ash in Tampa

Fig. 15
Leaving Tampa

Fig. 16
Sea voyage to Almirante

Fig. 17
Arrival in Almirante

Fig. 18
Arrival in Almirante

Fig. 19
Pneumatic unloader

Fig. 20
Floating pipeline

Fig. 21
Truck loading

Fig. 22
Trucking to project

Fig. 23
Discharge of RCC

Fig. 24
RCC plant and RCC dam

7. CONCLUSION

The Changuinola I project required 260.000 tons of cement and fly ash. Of this quantity 40.000 tons was imported in Big Bags during the first two years of the project. Over 220.000 tons were supplied between December 2009 and March 2011 for construction of the RCC dam. The system ultimately delivered a peak capacity of 30.000 tons per month, meeting the peak planned RCC production schedule, and not delaying the RCC placement. Its peak daily delivery to the project was 56 trucks of combined fly ash and cement, or approximately 1.650 tons. The cement and fly ash supply system fully met the RCC placement requirement and its initial planning assumptions.

The feature that made this cement and fly ash supply system unique, effective, and successful was incorporation of the floating terminal Lavioletta. With its ability to operate without the need of port facilities, just needing a sheltered berth, it gave the project the capability to have an overseas supply of the cement and fly ash with all the benefits of enhanced supply economics and supply choices.