High Speed Conveying

India's first Elevated, Triangulated Gallery Overland Conveyor

In 2010 The Adani Group broke ground on a new solid cargo handling port at the city of Dahej. Part of the material handling system is a unique conveyor system that moves up to 6000 tonnes per hour to a rail loading silo approx. 4.75 kilometres from the port.

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In March 2013 the Adani Group commissioned two high speed (7.5 m/s), elevated, horizontally curved conveyors (1100 m radius), that transport 6000 t/h of coal from the Dahej Port to a wagon loading silo. These conveyors are supported by unusual lightweight triangular galleries spanning 36 m each and weighing only 209 kg/m. The triangular galleries do not include walkways and are maintained with a motorized trolley. This article discusses the design and construction of this unusual conveyor system.

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Introduction

Located in the Gulf of Khambhat in the Bharuch district of Gujarat on the west coast of India, the Adani Group's new solid cargo handling port at the city of Dahej includes two fully mechanised deep draft berths for excavating coal from cape class vessels at a rate of 4600 t/h. Excavated coal is transported by conveyor to two stockpiles holding 125 000 t apiece. Two 2500 t/h reclaimers discharge coal from these stockpiles onto Yard Conveyor J10C1. The discharge chute at the head end of J10C1 includes a diverter gate that allows operators to either direct coal to a truck loading conveyor, or direct coal to the "Silo Conveyor" system that moves up to 6000 t/h to a rail loading silo approximately 4.75 km from the port. From the silo, coal is transported by a private Adani rail network to an Indian Railways station.

Conveyor Dynamics, Inc. (CDI) was initially awarded a contract by PMC Projects (a subsidiary of the Adani Group) to produce a basic engineering design of the elevated Silo Conveyors, and a basic engi-

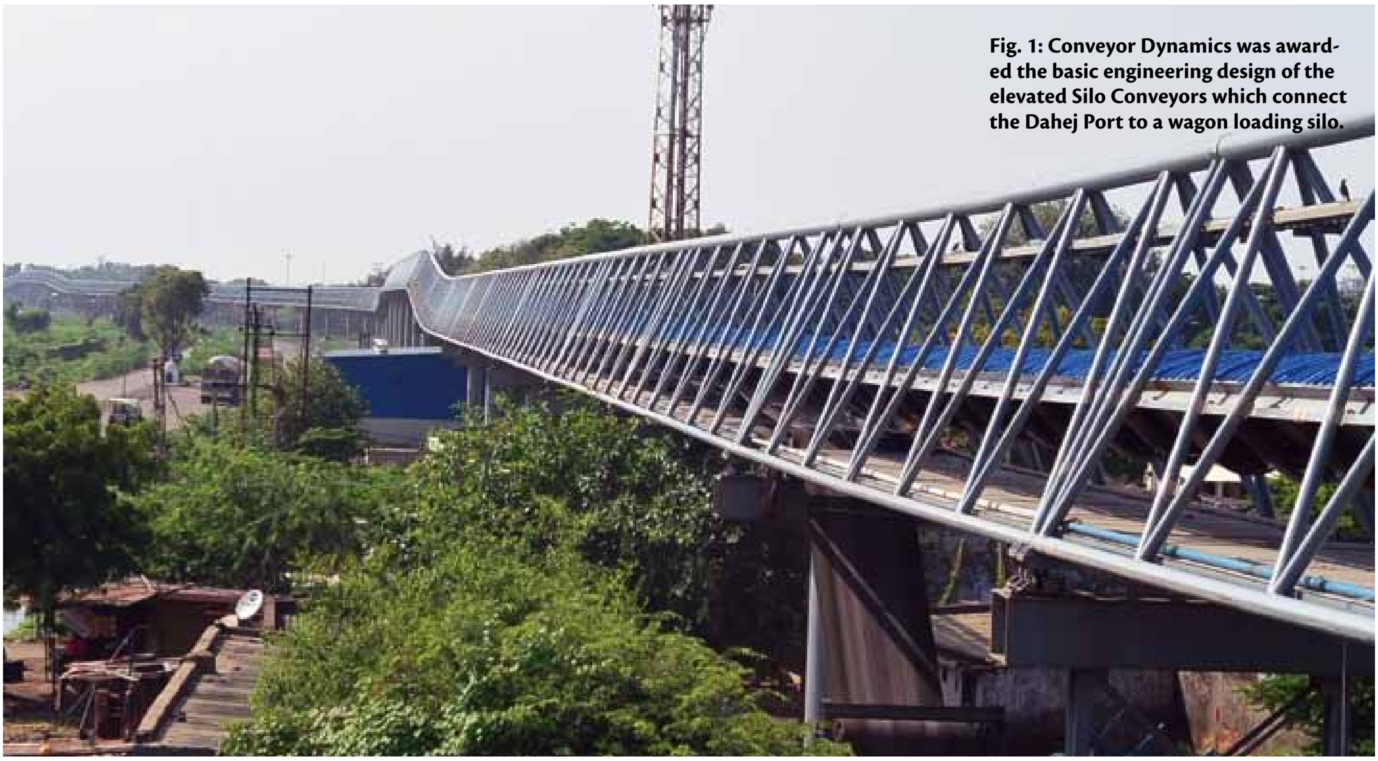

Fig. 1: Conveyor Dynamics was awarded the basic engineering design of the elevated Silo Conveyors which connect the Dahej Port to a wagon loading silo.

Pictures: Conveyor Dynamics

neering design for the Adani Power Conveyor system PMC intends to build in the future to transport coal from the terminus of the second silo conveyor to a new power plant they will build 10.85 km away.

After CDI completed the basic engineering, PMC realized that acquiring the land in the conveyor corridor posed a significant challenge. To avoid large change orders, the Adani group decided to handle all procurement, construction, and project management in-house. CDI was awarded a new contract to supply PMC with detail engineering design drawings of the silo conveyors and their supporting structures as well as a control philosophy. CDI also provided consulting services during fabrication, and support services during commissioning of the silo conveyors. The transfer house detail drawings were supplied by Elecon Engineering (Elecon). All electrical and instrumentation work including PLC logic development and programming was completed by Larsen and Toubro (L&T). Project management was handled directly by PMC.

System Overview

The Silo Conveyor system is comprised of three conveyors connected in series that transport up to 6000 t/h of coal from the Dahej port to a rail wagon loading silo.

The first conveyor in the series is SC-1A (Silo Conveyor 1A). SC-1A is 1.6 km long and gains 6.7 m of elevation. It transports up to 6000 t/h on an ST1000 1600 mm wide belt traveling 7.5 m/s. Two horizontal curves with 1100 m radii and nine vertical curves with various radii are included in the conveyor route. Most of the conveyor is located in an elevated gallery that is 6 m above the ground except where the conveyor crosses roads. Here the gallery elevation rises to 9 m above the road grade. SC-1A is powered by two 500 kW invertor driven motors, and includes two brakes. One brake is located on the tail pulley, and the other is located within the take-up sheave assembly. This second brake is used to boost the take-up tension during an unpowered stop.

SC-1A discharges onto the second conveyor in the series tagged SC-2A. SC-2A is 1.4 km long and gains 8.7 m of elevation. It transports up to 6000 t/h on an ST1000 1600 mm wide belt traveling 7.5 m/s. Like SC-1A the entire conveyor is elevated at least 6 m off the ground. It is powered by two 500 kW invertor driven motors. Currently, SC-2A directs feed onto a 485 m long low speed conveyor tagged SC-3. However, SC-2A's discharge chute includes a diverter gate that will allow SC-2A to discharge coal onto the Adani Power conveyor system in the future. SC-3 discharges coal into the rail wagon loading silo.

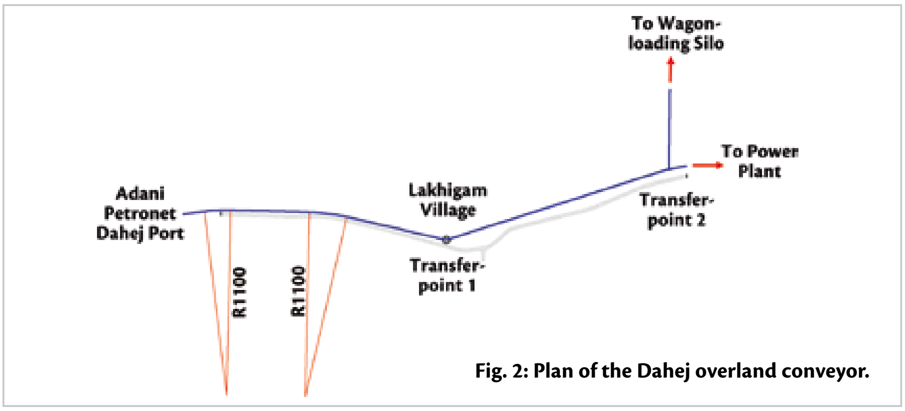

Fig. 2: Plan of the Dahej overland conveyor.

Route Optimisation

The route selected for the silo conveyors was tightly constrained by a number of existing industries occupying most of the land outside the port, by Lakhigam village, and by a large road. The conveyors could not pass outside a 5 m wide corridor between the road and surrounding developed properties. CDI was able to eliminate two transfer houses that were in the original feasibility study using tight 1100 m radius horizontal curves. However, we could not design a conventional conveyor with a curve tight enough to avoid a transfer station outside Lakhigam village. The final route is shown in Fig. 2.

Engineering horizontal curves like the two in this system is an iterative process. First, a rough profile of the conveyor is selected. The tensions along the conveyor route are computed and used to determine the minimum horizontal curve radius that the conveyor can safely negotiate. The tension prediction must be accurate and requires drag prediction using rubber rheological equations [1] and dynamic analysis [2]. After determining the belt tensions, a new route is selected and the horizontal curves and tensions for the new route are computed. The process is then repeated.


Fig. 3: High speed idler rollers have been used to allow for a belt speed of 7.5 m/s.


Fig. 4: Laydown yard of the tubular triangular conveyor galleries.


Fig. 5: Custom idler jig for positioning the idlers in horizontal curves.


Fig. 6: The maintenance trolley allows personnel access to the conveyor.

Fig. 7: The belt trough-stringer-hoodcover shields the coal from wind.

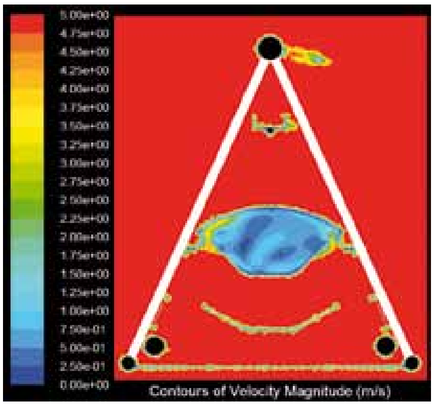

Fig. 8: CFD simulation of the gallery: wind generates negligible airflow above the belt.

Unusual Features of SC-1A

SC-1A is designed with a number of unusual features including:

- High Speed: only one other conveying system in India runs as fast as Dahej – the Mundra Port overland system, a collaborative design effort between CDI and Elecon.
- Lightweight: the triangular galleries supporting SC-1A weigh only 209 kg/m and span 36 m apiece. This is half the weight and 50% more span than the typical box style conveyor gallery.
- Motorised Maintenance Trolley: to save weight, the triangular gallery does not include walkways. Workers maintain the system using a motorised trolley.
- Horizontal Curves: the 1100 m radius horizontal curves are among the tightest radius horizontal curves in the world for 1600 m wide conventional steel cord troughed conveyors.
- Low Dust: an integrated low profile stringer-hood completely encloses the coal removing the need for side cladding on the gallery to prevent the release of dust into the environment.
- Low Rolling Resistance Belt: The bottom cover of the Dahej conveyor uses a low rolling resistance rubber compound that provides substantial power savings over the lifetime of the system.
- Low TIR idlers: All installed idlers had a Totel Indicator Run-out (TIR) of less than 0.4 mm. This reduced the friction and noise generated by the conveyor.

High Speed Conveying

Operating SC-1A and SC-2A at 7.5 m/s reduced the capital expense of the system and reduced the belt tension in SC-1A allowing the conveyor to bend through tighter horizontal curves. However, operating these conveyors at high speeds reduces the life of their belts compared to identical belts running slower. This is because most belt wear occurs in the loading zone and, all else being equal, a high speed belt sees the loading zone more often than a low speed belt. Since SC-3 is much shorter than SC-1A and SC-2A, it is designed to operate at 4 m/s to reduce the frequency of belt replacement on this conveyor.

Since the speed of SC-3 is 4 m/s instead of 7.5 m/s, the belt width of SC-3 is 2200 mm – far wider than the 1600 mm wide belts installed on SC-1A and SC-2A. In addition to the increased width, the weight of the SC-3 belt is 59 kg/m, almost 50 % more than the weight of the SC-1A and SC-2A belts which weigh 42 kg/m. On SC-3 the linear weight of material on the belt is 476 kg/m whereas on SC-1A and SC-2A the increased speed reduced the linear weight of material on these belts to 264 kg/m. Reduced linear weight reduces the belt tension necessary to control sag, reduces the indentation losses, and reduces the tension required to lift the material. This reduces overall belt tension which improves belt tracking in the horizontal curves. The narrower belt also shortened the idler roll length from 816 to 594 mm reducing the weight and cost of the idlers.

The narrow belt reduced the width of the elevated gallery, cutting the weight, strength and space requirements for the gallery. These reductions reduce the capital investment.

However, the tolerances allowed for high speed conveyor components are substantially tighter than their equivalent low speed counterparts. In particular, to reduce vibration and noise and extend idler life, CDI recommends that idler TIR not exceed 0.4 mm at 7.5 m/s.

Only a few companies in the world can consistently manufacture idlers with 0.4 mm TIR. The typical welded end disk idler assembly usually fails to meet spec because the welding process warps the shell. Several leading edge manufacturers have approached the problem by designing press fit end disks. This is the approach Elecon chose when they designed a special idler roll just for Dahej (Fig. 3). The result was an idler with consistant low TIR.

Tubular Triangular Gallery

The tubular triangular elevated conveyor gallery used at Dahej was not a new concept [3]. In his 2001 paper Staples estimated that the tubular conveyor gallery is about 40 % cheaper than the widely used box gallery style conveyor and recom-

Fig. 9: Gallery jigs.

Fig. 10: Bent laydown yard.

mended that all elevated overland conveyors adopt this design. However, the design of such galleries is not trivial.

Prior to working on the Dahej system, CDI designed two triangular gallery supported conveyors in Nigeria. CDI and Exclusive Technical Service (now part of Sandvik) collaborated on their first triangular gallery conveyor for the Dangote Cement plant in Nigeria [4]. Later, in 2009, CDI worked with Zigong Industrial Machinery in China to design and install a second triangular gallery conveyor at Dangote parallel to the first conveyor. In both of these cases CDI provided only GA drawings.

At Dahej, CDI was responsible for all detail design drawings of the conveyor gallery. This was the first time CDI created complete detail drawings of the triangular galleries. It was also PMC's first time constructing triangular galleries. Our engineering teams needed to work closely to create a practical design.

Meeting the tight structural tolerances specified by CDI to minimize vibration on the high speed conveyor proved a significant challenge for PMC particularly in horizontal galleries. Precise alignment was further complicated by the introduction of camber. Each 36 m gallery was constructed from three 12 m modules. Precisely fabricated wedges were butt welded between these modules to create a single 36 m long cambered gallery. Ultimately PMC designed a jig system to control the conveyor alignment to within the straight and horizontally curved galleries. This jig system controlled the belt centerline to within ±1 mm.

PMC fabricated all galleries and bents in a laydown yard at the port (Fig. 4). The gallery design could not accommodate training idlers and PMC engineers recognized that field adjustment of the idlers during commissioning would be difficult. To avoid belt training issues, the locations of the idlers were controlled to within 1 mm. In the horizontal curves a custom idler jig was used to position the idlers (Fig. 5). The work paid off as no idler adjustments were required during commissioning.

Conveyor Maintenance

Walkways substantially increase the weight of conveyor galleries. To eliminate this additional weight, CDI designed and provided detail drawings for a triangular maintenance trolley that allows maintenance personnel access to the conveyor (Fig. 6). In the past CDI had provided only GA drawings of the trolley. The Dahej trolley was the first trolley for which CDI created a complete set of electrical and mechanical drawings which were given to Elecon so that they could manufacture the trolleys at their plant in Gujarat.

Fig. 11: Erecting the first bent.

Fig. 12: Installing a gallery.

Dust Control

Coal dust generation was a major concern at Dahej, particularly where the conveyor passes through Lakhigam Village. Instead of enclosing the entire gallery with cladding, the belt trough-stringer-hoodcover were designed to form a single aerodynamic section that shields the coal from wind (Fig. 7). The design was validated using computational flow dynamics (Fig. 8). Installing side cladding on the gallery would have made idler inspection from the trolley very difficult. The low profile hood cover prevents personnel from viewing the top side of the belt. Alignment of the conveyor can be visualized from the underside of the belt. Heat detection systems are critical as it is not possible to see a fire on the belt outside of the transfer towers.

To further reduce dust, a Dry Fog Dust Suppression (DFDS) system was installed at each conveyor discharge point to control dust generated in the chutes.

System Erection

Since the conveyor system passes through both residential and industrial areas, minimizing the inconvenience and disruptions to the local community was an important consideration. PMC created a strategic plan for each and every gallery, mapping the approach through the village to ensure fast safe erection of the galleries.

Once the land issues were resolved construction proceeded rapidly. As land was acquired foundations for the conveyor support columns were poured. After completing the foundations, the bents and 36 m long galleries were moved out of the port on 24 m long trailers. In total, 86 triangular galleries travelled 2 to 4 km along the main village road, before reaching the conveyor where they were quickly installed using cranes. Final gallery positioning was completed with the assistance of a surveyor to maintain the ±1 mm conveyor centreline accuracy.

Conclusions

In India, acquiring land is challenging and conveyor systems often must allow local populations to freely pass through the conveyor corridor. Free movement is best facilitated by elevating the conveyor system, but this can become cost prohibitive. A triangular gallery with a motorised maintenance trolley is a practical structure for economically supporting elevated conveyors. In addition to the light weight structure, high speed conveying and horizontal curves offers further reduction in capital investment costs.

This paper outlines the engineering and construction challenges faced when constructing these conveyors. The authors hope the Dahej conveyor design can offer a benchmark for modern overland conveyor design. ■

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