EFFICIENT ELEVATED CONVEYOR STRUCTURE AND BETTER MAINTENANCE USING SELF POWERED TROLLEY

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Abstract

With overland conveyors crossing populated area and difficult terrains, long stretches of the conveyor structure are often elevated above ground. Conventional design uses walkways attached to the elevated structure to provide maintenance access. Using a self-powered trolley that moves on the conveyor structure can eliminate the walkway. The cost of the walkway is high when the conveyor length is long. The maintenance is also difficult, inefficient, and unsafe when workers have to walk long distances to inspect and replace parts. Project examples and cost benefits analysis of using the self-powered trolley are illustrated.

Introduction

Modern overland belt conveyors extend over kilometers or even tens of kilometers long. Under ideal conditions, the overland conveyor structure is supported on sleepers or concrete pillar foundations. The conveyor structure, including hood cover, stands about 1.5 to 2m above ground. Figure 1 shows a typical light weight ground based conveyor structure (Australia's Muja overland conveyor designed by Conveyor Dynamics, Inc. (CDI), with detail engineering and construction by Laing O'Rourke Australia) (1). The conveyor stringer is made from light weight sheet metal, weighing less than 100kg/m including idler frames. The low-profile hood cover provides better wind resistance. There is a permanent road that goes along side the overland conveyor. Maintenance crew drive a truck on the road to inspect and service the conveyor. The ground based conveyor structure is cost efficient and maintenance friendly. The requirement is that the area is sparsely populated by humans and animals, because the conveyor blocks traffic from either side. The service road, in most cases, is the private property of the conveyor operator and doesn't see much public traffic. The terrain needs to be relatively flat, without difficult undulation from hills, valleys, and rivers.

Figure 1. Low Profile Ground Based Conveyor – Australia Muja Overland Conveyor

The problem is that we are now living in an ever more crowded world, with increasing demand for resources, space, and preservation of environment. The demand for more resources prompts mining to move into more remote, less accessible areas, making the civil cost of a ground based structure prohibitively expensive. The competition for space requires that the conveyor structure doesn't block traffic or pose a safety hazard to residents, which is especially true in high-population countries like India and China. Lastly, the preservation of the environment requires that overland conveyors have a smaller foot print and less impact on the vegetation.

Compared to the elevated structure, underground conveyor in tunnels can also meet these requirements. However, the civil cost of tunnel construction is expensive. Geological uncertainties can also add risk and delay. Elevated overland conveyors offer an economic solution and are becoming more popular to meet both the ever more stringent space constraints, and environment protection.

Comparison of Cost and Maintenance between Using a Walkway and a Trolley

Conventional elevated overland conveyors use box steel trusses, supported by steel or concrete trestles. Such box truss is ubiquitous, the engineering and manufacturing of which are well practiced throughout the world. Using box truss to support elevated conveyors are common for plant conveyors. All concrete, freeway like structure is also used to support conveyors, but not typical. The span between support bents is generally between 15m and 25m. Figure 2 shows a conventional elevated conveyor used in CDI designed China Taihe overland conveyor (detail engineering and construction by Huadian Heavy Industries China). Heavy bridge type box trusses are used when the span is required to increase beyond 30m to cross roads. A walkway is on either side of the conveyor.

Figure 2. Conventional Elevated Steel Truss– China Taihe Overland Conveyor

From the cost perspective, a walkway is expensive in two aspects. First, the cost of the walkway is substantial. Typical two-side walkway, including guard rails, weighs 120kg/m. 1km of two-side walkway weighs 120 metric tons. Second, a walkway adds to the weight and cost of steel trusses, which not only needs to support the walkway but also the specified load on the walkway. For example, ASCE 7-10 (Minimum Design Loads for Buildings and Other Structures) stipulates that the load on walkway is 293kg/m^2. For 20m long truss, if the walkway width is 0.8m, the load on two-side walkway adds 9376 kg, or 469kg/m weight that the truss has to support, in addition to the weight of walkway. This additional walkway load is comparable to the structural weight of a typical medium tonnage conveyor. An estimate is that the steel truss will add at least 50kg/m weight so that it is strengthened to support the walkway and its load.

Assume the cost of walkway is $2000 US dollars per metric ton, Table 1 shows the cost difference between a box truss with walkway vs a triangular truss with trolley. Including all cost savings, the triangular truss with trolley can reduce cost by half million dollars per km length of conveyor.

Table 1, Cost Comparison between Box Truss with Walkway vs Triangular Truss with Trolley

Conveyor Length (km)	1	5	10
Total Walkway Weight (tons)	120	600	1200
Walkway Cost (million USD)	0.24	1.2	2.4
Additional Truss Cost[1] (million USD)	0.1	0.5	1.0
Cost Saving from Triangular Truss[2] (million USD)	0.2	1.0	2.0
Total Cost Difference (million USD)	**0.54**	**2.7**	**5.4**

1. 50kg/m additional weight to steel truss to support walkway and its load.
2. A well-designed triangular truss can save 100kg/m structural steel compared to box truss.

An efficient trolley design will result in a fully loaded trolley weighing about 2000kg ~ 3000kg. This includes two maintenance workers, replacement parts, and tools. The trolley at the center of a steel truss between two bents represents the worst load case, which is a concentrated load at the center of the beam. The concentrated load adds more stress to the truss than the distributed load of the same magnitude. If the trolley design is efficient in controlling the overall weight, the design can result in significant savings in the cost of steel trusses.

The nature of most elevated overland conveyors determines that a service road may not be available along with the conveyor. To maintain the conveyor, the maintenance crew will have to walk on foot and carry tools and replacement components. Typical walking speed is around 3 to 5km per hour. If carrying a load, the walking speed is even slower. This renders the maintenance much less efficient and more expensive. A properly designed self-powered trolley can move at 3m/s, or 11km per hour, doubling the speed of trekking on the walkway. This means accessing the maintenance point and completing regular inspection using 50% less time.

Triangular Truss with Self-powered Trolley

Compared to box steel truss made of hot rolled sections, the triangular truss is made of steel pipes. The pipes are either bolted or welded together. The conveyor is placed inside of the triangle. The triangular truss is capable of doubling the span between bents compared to a conventional box truss. Fewer bents reduce civil, construction cost and construction time. However, even with the increased span, the triangular truss is light weight, weighing less than comparable box truss. This is due to the unique triangular shape, and the fact that hollow circular pipes have better bending properties than hot-rolled steel sections with the same weight. Although steel pipes are more expensive than hot rolled steel sections, the lighter weight, reduced civil cost and less construction time, offer a superior solution for using the triangular truss. Table 2 lists the commissioned overland conveyors using a triangular truss that are designed by CDI (2).

Table 2, Overland Conveyor using Triangular Truss

Project	Conveyor Length (km)	Triangular Truss Span (m)
Nigeria Dangote Obajana Line 2 2400 T/H	6.7	36
Nigeria Dangote Obajana Line 3 3500 T/H	7.1	30
India Dahej 6000 T/H	1.6	36

Figure 3. Triangular Truss with Trolley. Top: India Dahej 6000 T/H coal conveyor; Bottom: Nigeria Dangote 2400 T/H (right) and 3500 T/H (left) limestone conveyor

Box Truss with Self-powered Trolley

Self-powered trolley can also be used on conventional box truss made from hot-rolled steel sections of I beams and angles. Figure 4 shows a self-powered trolley on a box truss, designed by Brazil's Tecnometal for the 4.3km Itaqui overland pipe conveyor near Sao Luis, Brazil. The pipe conveyor system is designed by Conveyor Dynamics, Inc., and commissioned in 2013 (3, 4). To better illustrate the characteristics of the trolley and truss, the figure shown here is when the pipe belt was not installed yet. Another example of self-powered trolley on box truss is the Lafarge 17km overland limestone conveyor crossing India and Bangladesh (5).

Figure 4. Brazil Itaqui Pipe Conveyor: Box Truss with Trolley

Self-Powered Trolley Design Considerations

Typically the drive unit is placed on top of the trolley, and work platforms are on the side. The work platform can accommodate two people for an efficient trolley frame design. For trolleys on triangular truss, there are two driven wheels on the top strand of the triangular truss. For trolleys on box truss, there are four driven wheels running on the top edges of the box truss. The trolleys are constrained by non-driven wheels contacting the side of triangular or box truss. Additional driven wheels can be added, depending on the speed, incline, and decline requirement of the trolley, but will add to the cost and weight of the trolley. A bigger trolley can be designed to accommodate more people, but the heavy weight adds to the cost of the conveyor truss, which is more significant than the cost of a trolley for long overland conveyor.

There are multiple choices for drive unit design:

1. Hydraulic motor. A hydraulic motor is coupled to each drive wheel. A diesel generator drives a pump through electric motor, which provides power to the hydraulic motor. The hydraulic motor also has an integrated brake.
2. Diesel generator and electric motor. A diesel electric generator feeds power to a variable frequency drive (VFD), which drives electric motors coupled to drive wheels. Brakes are equipped to the drive wheels so that the trolley can stop on a slope.
3. Battery powered electric motor. Lead acid, Nickel metal hydride, or lithium battery, supplies DC power to DC motor via motor controller. The battery drive is quiet, which offers advantage when the maintenance crew try to detect faulty idler rolls by abnormal sound. However, battery reliability may become a problem if there is no proper housing for the battery unit to provide enough ventilation and shielding. The capacity and weight of the battery also limits the travel range.
4. All-terrain vehicles. It is an option for a self-powered trolley on box truss. A properly selected vehicle can be modified to add work platforms and guide wheels to run on a box truss, and meet the weight and load requirement of a self-powered trolley. Figure 5 shows a modified all-terrain vehicle on a totally enclosed box truss with a pipe conveyor inside. Compared to a custom made drive unit, the all-terrain vehicle has better reliability and drive performance in terms of speed and traction because it is made by specialized vehicle manufacturers.


Figure 5. Using Modified All-Terrain Vehicle as Trolley

Summary

Compared to the conventional design of using a walkway on elevated overland conveyors, the self-powered trolley without walkway offers the following benefits:

1. Saving cost of the structural steel by eliminating the walkway and reducing the weight of steel truss.
2. Lightweight triangular truss can further reduce structural weight per meter, and double the span between support bents.
3. Savings in structural steel cost is estimated to be 0.42 million dollars per km, between box truss with walkway and triangular truss with trolley.
4. Maintenance is easier and more efficient for a long overland conveyor, when the crew can ride the trolley instead of hiking up and down on the walkway.

A self-powered trolley can be used for both conventional box truss and lightweight triangular truss. There are multiple design choices available for the trolley to meet the weight, cost, and performance requirement.

References

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