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Pipe belt conveyor: cost estimation under various design constraints

1. Introduction

Pipe belt conveyors, also called tube conveyors are getting prominence for transportation of bulk material for certain advantages. Over a conventional open belt conveyor, the basic advantage is the pipe shape, that prevents leakages, reduces pilferage and also importantly, and produces little dust along its path of travel. As a result, it is being touted to be environmentally clean option. In the recent years, all over the world pipe belt conveyors of long distance are becoming increasingly common. As of today, the world's longest pipe conveyor, which is 8.2 km long and is operating in Peru, as well as the highest capacity coal pipe conveyor with a capacity of 2,000 tonnes per hour, operating in Colombia. India's longest (2.4 km) pipe conveyor, today carries 1000 tonnes of limestone per hour.

In this paper while we discuss the technicalities of pipe belt conveyor in general, we provide a case where the technical solution is derived. The team was asked make a techno-social- commercial decision to lay a pipe belt conveyor from the boundaries of a mine to a railway siding.

2. Pipe conveyor

The pipe conveyor is an enclosed curve going transportation system for all kinds of bulk materials. At the loading and discharging points, the conveyor system is identical with open troughed conveyors. The difference starts after the loading point, where the belt is formed into its typical tubular shape by special idler arrangements over a certain distance and finally is led through idler panels with hexagonal cut outs and offset idler arrangement (Fig.1). At the discharging point, the belt opens automatically after the final idler panel and transfers the material to its next destination.

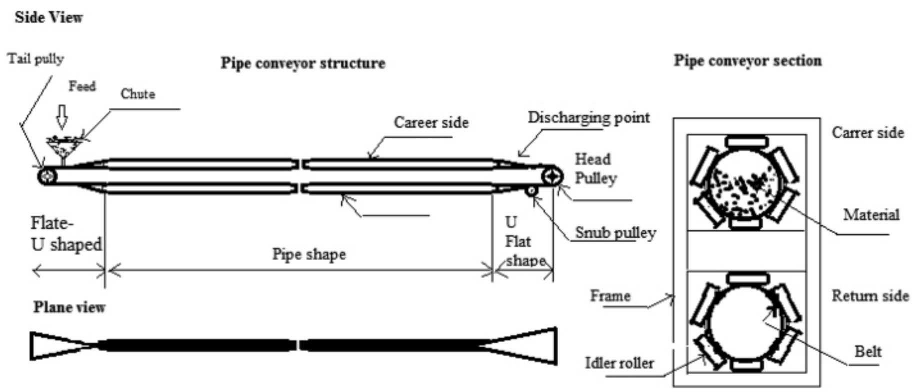

Fig.1 Plan and section of general pipe conveyor structure

Due to its tubular shape, the conveyor is able to manage horizontal and vertical curves as well as high inclinations. The enclosed transportation system not only protects the conveyed material against external influences such as climatic conditions, it also avoids material loss and spillage and thus, protects the environment.

2.1. The pipe conveyor belt

Same as conventional troughed conveyor, pipe conveyor is dependent on the belt tensions, the construction of a pipe conveyor belt could be of fabric or steel cord. However as the belt is required to form the pipe shape, several important structural features are employed in its design.

A special carcass construction is employed as the belt requires adequate stiffness as it is made to form the pipe passing through the idler rolls. Flexibility for transition from the flat to pipe shape at the feed end and pipe to flat at the discharge end is also essential. A layer of special rubber compound is usually placed between each fabric ply to achieve this. In addition top and bottom belt cover grades as well as curing times are specially controlled to prevent the belt's natural tendency to remember its pipe shape.

In steel cord pipe conveyor belts, transverse is used above and below the steel cables with a layer of rubber separating the fabric from the cords.

2.1.1. Application of pipe conveyors

Pipe conveyors find their application in virtually every industry for the transport of bulk solids. These include

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cement, fertilizer, coal, power, steel, pulp and paper, food grains etc. Pipe conveyors overcome several of the problems commonly associated with conventional conveyors, e.g. spillage of materials, belt training, limited angles of conveyance, horizontal curves and multiple flights.

Some of the difficult materials handled by pipe conveyors are cement, fly ash, gypsum, fluidized rock phosphate, alumina, sinter, sludge, wood chips etc. Pipe conveyors have also been developed as an alternate and significant energy saving device to pneumatic means of conveying of fine material

2.1.2. Applicability

Pipe belt conveyor can be useful in the transportation of sized coal from the mine site to the siding due to:

- Most importantly, it will prevent pilferage of coal because of the towers and pipe shape.
- The long terrain will have relatively drop, elevation, near 90 degree turn in the belt path where it will have better control in operation relative to the troughed belt conveyor.
- Ease of getting permission of diversion of forest land for non-forest purposes, acquisition and environmental clearance as well as linear projects like a belt conveyor usually get faster land and environmental clearances.
- Relatively less likely conflicts with farmers due to overland transport and non-spillage character of transport.
- In the following paragraphs we will discuss the globally accepted advantages and disadvantages of pipe conveyor transport.

2.1.3. Advantages

- Protection of the conveyed material against external influences
- Protection of the environment against escaping material by dust free transport
- Possibility of tight curve radii
- Realization of steep inclination
- Low space requirements
- No need for transfer towers
- Adaptation ability to topographic requirements
- Possibility of downhill transportation
- Low maintenance costs
- High operational safety
- Environmental protection and totally enclosed conveying. The material conveyed is protected from wind losses, spillage, contamination, rain and theft
- High angle conveying, generally a 50% higher angle of conveyance possible by pipe conveyors as compared to conventional troughed belt conveyors
- Ability to negotiate complex 3D profiles
- Reducing particle degradation resulting from transfer points
- Larger volume of material transported. A pipe conveyor transports the same volume of material as a conventional troughed belt conveyor of the size that of 2.5 to 3 times its pipe diameter
- Power saving, when a single pipe conveyor replaces several conveyors in a system, the total power consumed is considerably lower.

2.1.4. Disadvantages

- High energy consumption due to the higher drag of the closed belt.
- Higher belt width: 1.6 times the normal belt width for the same mass flow and the same belt speed of a trough shaped belt conveyor with a trough angle of 30.
- Sensitive against overload and oversize.
- Difficult to repair and dismantling of the belt.
- The facility requires more frequent maintenance and safety checks.
- Stored-up heat in the closed belt when conveying hot summer.
- If the material is sticky, e.g. during rainy season, belt cleaning can be difficult and generally not very successful.
- There is almost always material carry over from the belt discharge and this becomes a house keeping problem.
- If the material being conveyed is sticky it will ultimately get transferred to the return side of the belt and then to the rolls, idlers and pulleys, then belt tracking can be an ongoing issue.

2.2. Cross country pipe conveyor path

The cross country path after 3-5 years of conveyor development

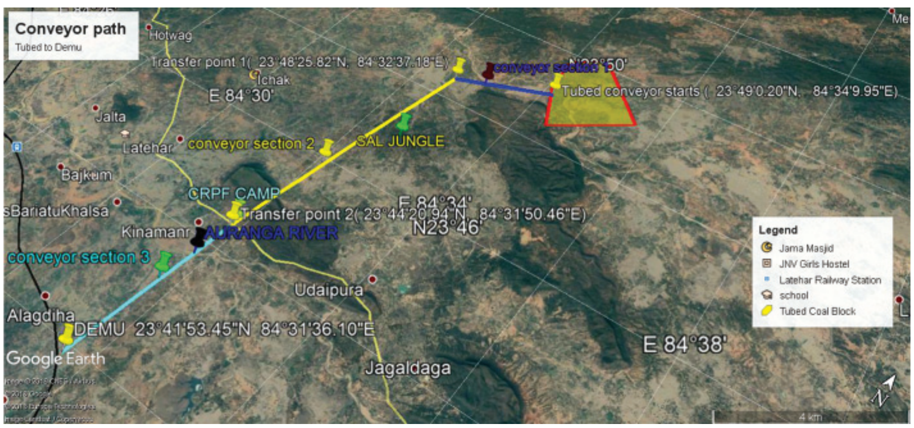


Fig.2 Conveyor path from TUEBD to DEMU

Tubed > Kaima > Demu

As per Fig.2, the conveyor starts from the western side of the mine boundary and passes through cultivated land of Kaima village (about 2 km cultivated land). Then continuing to 6-7 km (1.5 km sal jungle, and two village viz. Manikpur and Pandepur), it crosses a valley (about 1 km) between hill and meets at CRPF Camp side. After this it crosses over NH75 which is 15-18 ft. wide, from NH75 about 4.7 km leads to DEMU halt. Since the road connecting the position near CRPF camp site and DEMU station has to be built anyway for road transportation, the space for the belt conveyor can be alongside the road for better operational control.

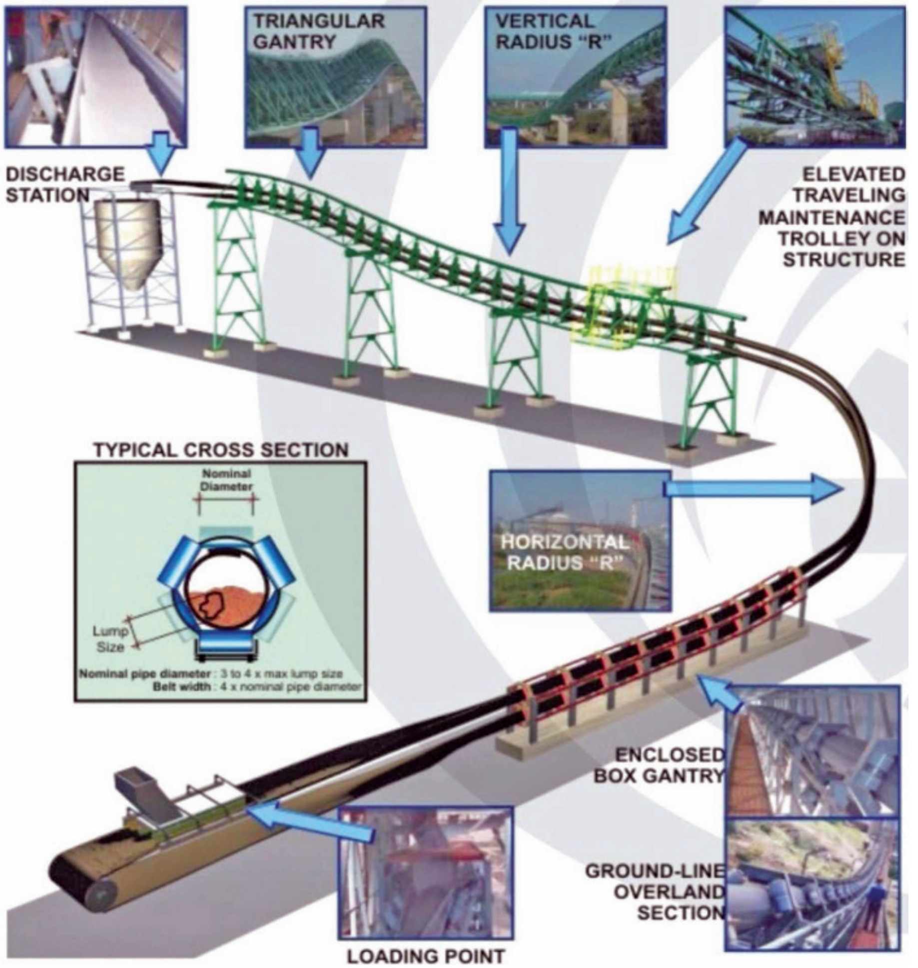


Fig.3 Schematic layout of pipe conveyor (Not own figure)

Since a single conveyor of 15.2 km in not efficient because of 90º curve, as losses are high in the bends. In the curve the pipe conveyor undergoes in tension on convex side and compression on concave side, so the wear and tear would be more needing frequent replacement, if the tension in belt is high which depends on the length of conveyor. That is why it is better to install in multiple sections.

We recommend the proposed conveyor length to be installed in three sections. It is also recommended because the parties may not have prior experience of running a long conveyor of such type.

1. Conveyor section 1

This section has a length of approximately 2.9 km and commences from western side of mine boundary (N23º48'58", E84º34'10"), passes through cultivated land of Kaima village (about 2 km cultivated land) to a point (N23º48'24", E84º32'37"). This section has almost level terrain having an average elevation of MSL 391m. The highest elevation of MSL 396 m is near the mine site (N23º48'58", E84º34'10"), and lowest point is approximately MSL 387m at transfer point 1(N23º48'24", E84º32'37").

Reason for choosing transfer point 1:

1. It is level terrain;
2. To avoid 90º bend;
3. There is no houses;

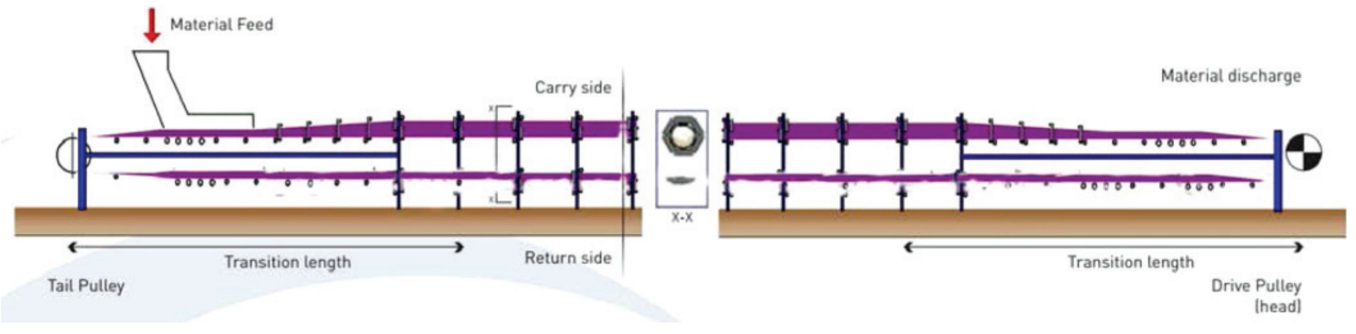


Fig.4 Design and function of the pipe belt conveyor (Not own figure)

4. After this point there is sal jungle which is not suitable as government may not allow from the environment point of view.

2. Conveyor section 2

It is approximately 7.6 km long, starts at transfer point 1 (N23º48'24", E84º32'37"), crosses sal jungle (1.5km wide) and passes through the outside of two villages Manikpur (N23º46'0", E84º32'8") and Pandepur (N23º45'32", E84º 32'3") and passes over the hill (1km), further crosses NH 75 at CRPF camp point (23º44'24", E84º 31'55") where it ends at a distance 200 m after crossing NH 75 (23º44'21", E84º31'5"). This terrain of section is somewhat undulating but good enough for the pipe conveyor. It has maximum elevation in sal jungle (MSL439 m) and minimum (MSL387m) at transfer point 1.

The reasons for choosing location of transfer point 2

- It is near NH75 (200m distance from the road and CRPF camp) having good access and 200 m away from the CRPF camp so that one can anticipate little legal problem.
- No cultivated land and no hills around.

3. Conveyor section 3

Starting from this section is 4.6 km long, commencing from Transfer point 2 23º44'21", E84º31'5"), crosses Auranga river (200m wide, N23º43'47", E84º31'47") and passes through Harkha village (23º43'36", E84º31'46"), finally lead to DEMU halt station.

The elevation of the terrain is approximately level having an average elevation of MSL 394 m. it has highest point of MSL 407 m at Demu halt Station (N23º41'54", E84º31'36") and minimum MSL at Auranga river (N23º43'47", E84º31'47").

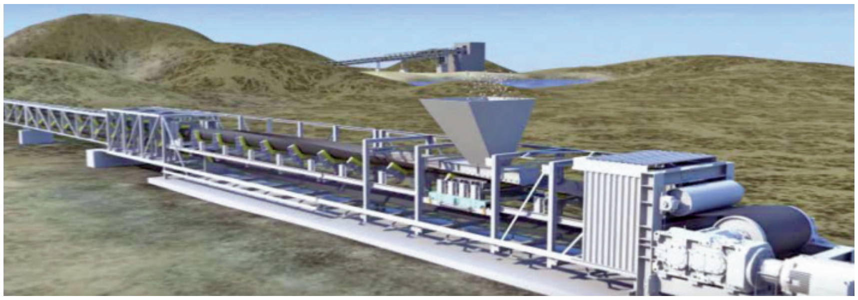
Total conveyor path length

= section 1 + section 2 + section 3

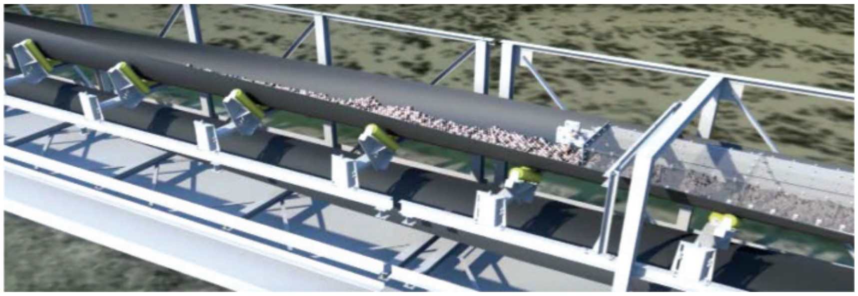
= (2.9 + 7.6 + 4.6) km

= 15.2 km

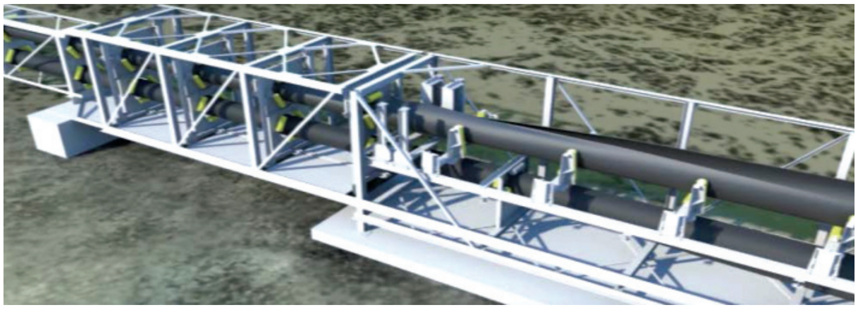
We have decided to make the belt conveyor section 2 and 3 separately, not



Typical view of loading point. The belt is flat here

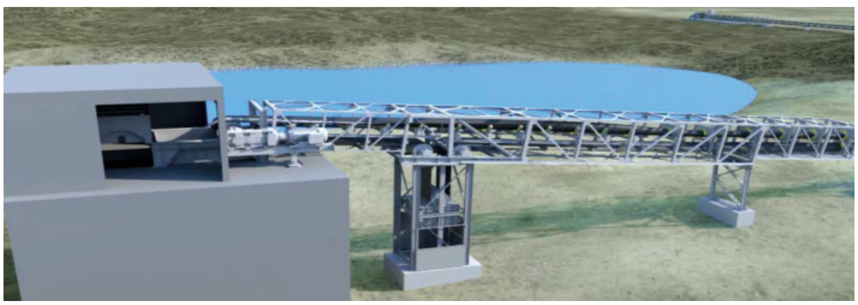


Belt before taking pipe shape



Belt after taking pipe shape

Pipe conveyor crossing over the road



Unloading point

Fig.5 Differerent places of pipe belt conveyor transportation a single pipe belt conveyor because section 2 will end at location from where if required the management will have road transport option. Further more than one transfer point means there will be some men employed which will provide better security.

3.4 Pipe conveyor layout

The proposed schematic of the pipe belt conveyor: Since there would be a requirement of nearly 90 degree turn at the belt conveyor will have three sections. For a belt path having elevation, drops and high turns (close to 90 degrees) it is not advisable to have one single belt because of high belt wear and tear, generally in normal running and particularly during summer and sharp day-night temperature changes. Belt cost being important (25-27% of the total cost is belt cost) it is liable to damage due to external tension and internal compression during bends, particularly during summer. If torn, belt splicing will take a minimum of 2 days with high cost. Bends are not usually preferred, transfer points are desired. Though initial investment becomes higher with transfers, in the long run for a long project duration, it substantially reduces revenue cost and overall cost and ease of maintenance.

The loading point will be at tubed near N23°48'58", E84°34'10" and the first section will end at N23°48'24", E84°32' 37" where it will have the material unloading/transfer for the next belt section.

3.5 Technical Calculations

As targeted production is 20000 tonnes per day, assuming 25% extra peak time production.

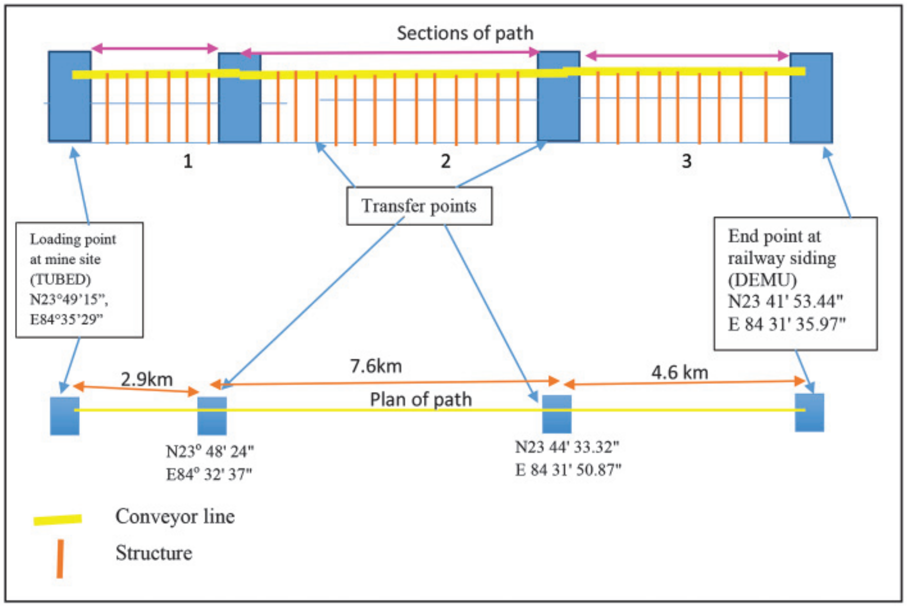


Fig.6 Layout of conveyor for current proposal

Now = 20000 + 20000*(25/100)

= 25000te/day

Considering operating hour per day for pipe conveyor = 20 hour/day

Therefore hourly capacity

Mass = 26000/= 1250 te/hr.

Volume = 1250/1.1

= 1136.0 m^3/hr.

= 40125 ft^3/hr.

= 40125 ft^3/hr. (approx.)

• Pipe conveyor design as per CEMA, USA:

Conveyor capacity:

Maximum lump size = 100mm

= 4 inch (approx.)

Required capacity = 40125ft^3/hr.

Table 1: Pipe conveyor capacity chart

Pipe Dia.	Material Cross section	Recommended maximum belt speed	Capacity		Maximum lump size (2)	Standard troughed conveyor equivalent (3)
(in.)	sq. ft.	(FPM)	(cu. ft./hr)	(tph)	(in.)	(in)
6	0.147	400	3528	176	2.00	18
8	0.262	430	6760	338	2.75	24
10	0.409	460	11288	564	3.50	24
12	0.589	500	17670	884	4.00	30
14	0.802	570	27428	1371	4.75	36
16	1.047	660	41461	2073	5.50	42
20	1.636	740	72638	3632	6.50	48
24	2.356	820	115915	5796	8.00	60
28	3.207	900	173178	8659	10.00	66
34	4.729	980	278065	13903	12.00	84

From Table 2 : pipe conveyor capacity chart

For 41461 ft^3/hr.: Belt speed is 660 fpm

Pipe diameter = 16 inch

Material load cross section = 1.047 ft^2

So for 40125 ft^3/hr., speed = 660*40125/41461= 638 fpm

A pipe conveyor capacity chart can be seen in Table 2.

- Based on 75% load cross section.
- Based on maximum lump side = 1/3 of pipe diameter.
- Based on 35E troughing idlers and 22E material surcharge angle.

Idler selection:

Standard idler spacing, for pipe dia. (D) 16 inch:

- Idler spacing is : 10'6" (up to 50pcf)

  : 6'0" (over 50pcf)
- Idler roll dia = 4 inch
- Idler bearing dia = 1 inch

Pipe conveyor transition distance:

From Table 3: for 16 inch pipe dia., for transition length (considering steel cord belt) = 67ft (22m). Interval between trusses should be from 8m to 30m (let us suppose 25.00 m interval), so for 15.2km, number of trusses = 15200/25 = 608 numbers.

3. Power requirement for pipe conveyor

3.1 Power requirement calculation

Effective tension

$T_e = L*K_t\,(K_x + K_y*W_b + 0.015W_b)$

$+ W_m\,(L*K_y \pm H) + T_p + T_{am} + T_{ac} + C_f$

K_t = Ambient temperature correction factor

K_x= idler friction factor (lbs./ft.)

By CEMA, K_x = .00068 $(W_b+W_m) + A_i/S_i$

Where

W_b = Weight of belt in lbs/Ft

Table 2 Pipe conveyor transition distance

Pipe diameter (Inch)	Fabric belt transition length (Feet)	Steel chord belt transition length (Feet)
6	13	25
8	17	34
10	21	42
12	25	50
14	29	58
16	34	67
20	42	84
24	50	100
28	59	117
34	71	142

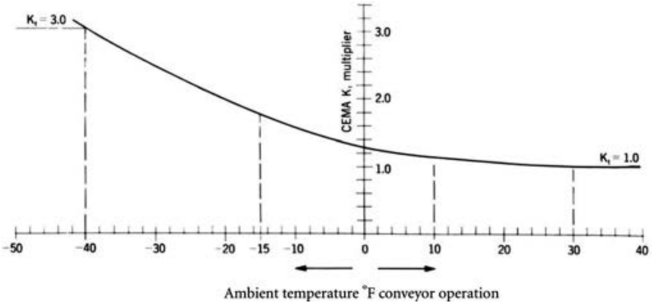


Fig.7 Graph for ambient temperature correction factor

W_m = Weight of material in lbs/Ft = 339 lbs/ft

.00068 = Coefficient of rolling friction for the idler bearings

S_i = Idler spacing in feet = 0.5ft

A_i = Seal and grease churning friction

CEMA standard and for pipe conveyor idler bearing diameter vs. CEMA standard. Trough belt aip term;

A_i CEMA = 1.5 for a CEMA C6 idler with: @ diameter bearing (3 rolls).

A_i Pipe = Ai CEMA × 6/7 × 2

(Base Value) = 1.5 × 6/7 × 2 = 2.6

Table 3: Pipe conveyor– Idler A_i values

Pipe diameter	Trough belt TAip	Return belt (RAip)			
		Case 1	Case 2	Case 3	Case 4
6	6.2	6.2	4.1	3.4	2.8
8	6.2	6.2	4.1	3.4	2.8
10	4.5	4.5	3.0	2.5	2.0
12	4.5	4.5	3.0	2.5	2.0
14	4.5	4.5	3.0	2.5	2.0
16	3.5	3.5	2.3	1.9	1.6
20	3.5	3.5	2.3	1.9	1.6
24	3.8	3.8	2.5	2.1	1.7
28	3.2	3.2	2.1	1.8	1.4
34	3.5	3.5	2.3	1.9	1.6

Table 4: Belt width v/s material carried (lbs/cu ft).

Belt width (inches (b))	Material carried, lbs/cu ft		
	30-74	75-129	130-200
18	3.5	4.0	4.5
24	4.5	5.5	6.0
30	6.0	7.0	8.0
36	9.0	10.0	12.0
42	11.0	12.0	14.0
48	14.0	15.0	17.0
54	16.0	17.0	19.0
60	18.0	20.0	22.0
72	21.0	24.0	26.0
84	25.0	30.0	33.0
96	30.0	35.0	38.0

TABLE 5: CORRECTED FACTOR K_y VALUE WHEN OTHER THAN TABULAR CARRYING IDLER SPACING ARE USED

$W_b + W_m$ (lbs/ft)	S_i (ft)	Reference Values of K_y for Interpolation									
		0.016	0.018	0.020	0.022	0.024	0.026	0.028	0.030	0.032	0.034
Less than 50	3.0	0.0160	0.0160	0.0160	0.0168	0.0183	0.0197	0.0212	0.0227	0.0242	0.0257
	3.5	0.0160	0.0160	0.0169	0.0189	0.0207	0.0224	0.0241	0.0257	0.0274	0.0291
	4.0	0.0160	0.0165	0.0182	0.0204	0.0223	0.0241	0.0259	0.0278	0.0297	0.0316
	4.5	**0.016**	**0.018**	**0.020**	**0.022**	**0.024**	**0.026**	**0.028**	**0.030**	**0.032**	**0.034**
	5.0	0.0174	0.0195	0.0213	0.0236	0.0254	0.0273	0.0291	0.0031	0.0329	0.0348
50 to 99	3.0	0.0160	0.0162	0.0173	0.0186	0.0205	0.0221	0.0239	0.026	0.0274	0.029
	3.5	0.0160	0.0165	0.0185	0.0205	0.0222	0.024	0.0262	0.0281	0.030	0.0321
	4.0	**0.016**	**0.018**	**0.020**	**0.022**	**0.024**	**0.026**	**0.028**	**0.030**	**0.032**	**0.034**
	4.5	0.0175	0.0193	0.0214	0.0235	0.0253	0.0272	0.0297	0.0316	0.0335	0.035
	5.0	0.0184	0.021	0.023	0.0253	0.027	0.029	0.0315	0.0335	0.035	0.035
100 to 149	3.0	0.0160	0.0164	0.0186	0.0205	0.0228	0.0246	0.0267	0.0285	0.0307	0.0329
	3.5	**0.016**	**0.018**	**0.020**	**0.022**	**0.024**	**0.026**	**0.028**	**0.030**	**0.032**	**0.034**
	4.0	0.0175	0.0197	0.0213	0.0234	0.0253	0.0277	0.0295	0.0312	0.033	0.035
	4.5	0.0188	0.0213	0.0232	0.0253	0.0273	0.0295	0.0314	0.033	0.0346	0.035
	5.0	0.0201	0.0228	0.0250	0.0271	0.0296	0.0316	0.0334	0.035	0.035	0.035
150 to 199	**3.0**	**0.016**	**0.018**	**0.020**	**0.022**	**0.024**	**0.026**	**0.028**	**0.030**	**0.032**	**0.034**
	3.5	0.0172	0.0195	0.0215	0.0235	0.0255	0.0271	0.0289	0.031	0.0333	0.0345
	4.0	0.0187	0.0213	0.0235	0.0252	0.0267	0.0283	0.0303	0.0325	0.0347	0.035
	4.5	0.0209	0.023	0.0253	0.0274	0.0289	0.0305	0.0323	0.0345	0.035	0.035
	5.0	0.0225	0.0248	0.0272	0.0293	0.0311	0.0328	0.0348	0.035	0.035	0.035
200 to 249	**3.0**	**0.016**	**0.018**	**0.020**	**0.022**	**0.024**	**0.026**	**0.028**	**0.030**	**0.032**	**0.034**
	3.5	0.0177	0.0199	0.0216	0.0235	0.0256	0.0278	0.0295	0.031	0.0327	0.0349
	4.0	0.0192	0.0216	0.0236	0.0256	0.0274	0.0291	0.0305	0.0322	0.0339	0.035
	4.5	0.021	0.0234	0.0253	0.0276	0.0298	0.0317	0.0331	0.0347	0.035	0.035
	5.0	0.0227	0.0252	0.0274	0.0298	0.0319	0.0338	0.035	0.035	0.035	0.035

TABLE 6: CORRECTED FACTOR K_y VALUE WHEN OTHER THAN TABULAR CARRYING IDLER SPACING ARE USED

$W_b + W_m$ (lbs/ft)	S_i (ft)	Reference Values of K_y for Interpolation									
		0.016	0.018	0.020	0.022	0.024	0.026	0.028	0.030	0.032	0.034
Less than 50	3.0	0.0160	0.0160	0.0160	0.0168	0.0183	0.0197	0.0212	0.0227	0.0242	0.0257
	3.5	0.0160	0.0160	0.0169	0.0189	0.0207	0.0224	0.0241	0.0257	0.0274	0.0291
	4.0	0.0160	0.0165	0.0182	0.0204	0.0223	0.0241	0.0259	0.0278	0.0297	0.0316
	4.5	**0.016**	**0.018**	**0.020**	**0.022**	**0.024**	**0.026**	**0.028**	**0.030**	**0.032**	**0.034**
	5.0	0.0174	0.0195	0.0213	0.0236	0.0254	0.0273	0.0291	0.0031	0.0329	0.0348
50 to 99	3.0	0.0160	0.0162	0.0173	0.0186	0.0205	0.0221	0.0239	0.026	0.0274	0.029
	3.5	0.0160	0.0165	0.0185	0.0205	0.0222	0.024	0.0262	0.0281	0.030	0.0321
	4.0	**0.016**	**0.018**	**0.020**	**0.022**	**0.024**	**0.026**	**0.028**	**0.030**	**0.032**	**0.034**
	4.5	0.0175	0.0193	0.0214	0.0235	0.0253	0.0272	0.0297	0.0316	0.0335	0.035
	5.0	0.0184	0.021	0.023	0.0253	0.027	0.029	0.0315	0.0335	0.035	0.035
100 to 149	3.0	0.0160	0.0164	0.0186	0.0205	0.0228	0.0246	0.0267	0.0285	0.0307	0.0329
	3.5	**0.016**	**0.018**	**0.020**	**0.022**	**0.024**	**0.026**	**0.028**	**0.030**	**0.032**	**0.034**
	4.0	0.0175	0.0197	0.0213	0.0234	0.0253	0.0277	0.0295	0.0312	0.033	0.035
	4.5	0.0188	0.0213	0.0232	0.0253	0.0273	0.0295	0.0314	0.033	0.0346	0.035
	5.0	0.0201	0.0228	0.0250	0.0271	0.0296	0.0316	0.0334	0.035	0.035	0.035
150 to 199	**3.0**	**0.016**	**0.018**	**0.020**	**0.022**	**0.024**	**0.026**	**0.028**	**0.030**	**0.032**	**0.034**
	3.5	0.0172	0.0195	0.0215	0.0235	0.0255	0.0271	0.0289	0.031	0.0333	0.0345
	4.0	0.0187	0.0213	0.0235	0.0252	0.0267	0.0283	0.0303	0.0325	0.0347	0.035
	4.5	0.0209	0.023	0.0253	0.0274	0.0289	0.0305	0.0323	0.0345	0.035	0.035
	5.0	0.0225	0.0248	0.0272	0.0293	0.0311	0.0328	0.0348	0.035	0.035	0.035
200 to 249	**3.0**	**0.016**	**0.018**	**0.020**	**0.022**	**0.024**	**0.026**	**0.028**	**0.030**	**0.032**	**0.034**
	3.5	0.0177	0.0199	0.0216	0.0235	0.0256	0.0278	0.0295	0.031	0.0327	0.0349
	4.0	0.0192	0.0216	0.0236	0.0256	0.0274	0.0291	0.0305	0.0322	0.0339	0.035
	4.5	0.021	0.0234	0.0253	0.0276	0.0298	0.0317	0.0331	0.0347	0.035	0.035
	5.0	0.0227	0.0252	0.0274	0.0298	0.0319	0.0338	0.035	0.035	0.035	0.035

The pipe conveyor A_i value must also be adjusted for other roll diameters and bearing diameters. Roll diameters greater than 6" will reduce A_i, while rolls less than 6" will increase A_i. The roller bearings also effect the A_i term. Bearings larger than .75" will increase the value of A_i and bearings smaller than .75" will lower the A_i value. This can be calculated as follows:

Pipe A_i (Aip) = 2.6 × 6/roll dia. * Brg dia./75

Trough belt K_{xt} = .00068 (W_b+W_m) +TA_ip/Si

W_b= weight of belt, lbs/ft

For belt width 54 inch (width equivalent to 16 inch dia. pipe tube) and 81 lbs/ft^3 material

W_b = 27 lbs/ft (150% of 17) (from Table 5)

TA_ip = 3.5 lbs

W_m = 113 lbs/ft

So K_{xt} = .00068 (27+113) +3.5/.5 = 7.0952 lbs/ft

Return belt K_{xr}= .00068 W_b + RAip/Si

= .00068*27 + 2.3/.5

= 4.61836 lbs/ft

K_x = K_{xt} + K_{xr} = 11.71356lbs/ft

3.1.1. K_y – *Factor for calculating the force of belt and load flexure over the idlers*

CEMA defines the K_y term as the resistance of the material flexure over idler rolls. These values are a function of the material and belt weight per foot, belt tension and idler spacing. CEMA defines the range of K_y as .016 to .035 and uses .015 for return belt K_y. The K_y factor = *s* presented in CEMA are based on a maximum idler spacing of 5' - 0" and are shown to increase with spacing. This results from increased belt sag distance (assuming sag % is a function of idler spacing) and hence greater flexure. For pipe conveyors over 8" diameter the idler spacing exceeds the 5' - 0" CEMA maximum but the deflection is much less because of its pipe shape compared to a flat belt. Since the K_y term is influenced by deflection we suggest using the K_y values tabulated for the three (3) foot spacing but, as with CEMA, limit this value to .016 as a minimum.

We have: W_b+$W_{–m}$ = 140lbs/ft

S_{-i-} = 0.5feet

K_y = .0246 (from table)

T_p = tension resulting from resistance of belt to flexure around pulleys and the resistance of pulleys to rotation on their bearings, total for all pulleys, lbs

Considering dual-pulley drive on return run; regenerative type:

From Table 6:

2 × 200 = 400 lbs = 200 kg – tight side

3 × 150 = 450 lbs = 225 kg – slack side

TABLE 7: BELT TENSION TO ROTATE PULLEYS

Location of pulleys	Degree wrap of belt	Pounds of tension at belt line
Tight side	150^o to 240^o	200 lbs/pulleys
Slack side	150^o to 240^o	150 lbs/pulleys
All other pulleys	Less than 150^o	100 lbs/pulleys

Note: Double the above value for pulley shafts that are not operating in antifriction bearings.

TABLE 8: CIRCULAR FORMING FRICTION (C_f) TO BE ADDED FOR EACH FLAT TO ROUND TRANSITION

Pipe diameter (inch)	Additional teC_f (lbs)
6	50
8	60
10	70
12	80
14	90
16	100
20	120
24	130
28	150
34	180

TABLE 9: POWER CALCULATION

Conveyor number	Effective tension Te = L*K_t (K_x+K_y*W_b+0.015W_b) +W_m(L*K_y±H)+T_p+T_{am}+T_{ac}+C_f	Tension T_e(lbs)	Power (Hp)= (Te×V)/ 33,000
1	9515*1*2*(11.71356+.0246*27 +.015*27)+113*(9515*0.0246 –29.53)+950+230+0+100	267648 (1190kN)	5353
2	22966*1*2*(11.71356+.0246*27 +.015*27)+113*(22966*0.0246 +13.12)+950+230+0+100	653741 (2906kN)	13075
3	15092*1*2*(11.71356+.0246*27 +.015*27)+113*(15092*0.0246 +52.5)+950+230+0+100	435000 (1933kN)	8700
	Total power		27128hp (20230kW)

TABLE 10: MINIMUM SLACK SIDE TENSION REQUIRED FOR 420^o WRAP ANGLE

Conveyor section	Wrap factor (C_w)	T_2=$T_{e*}C_w$
1	0.18	48184
2	0.18	117680
3	0.18	78307

TABLE 11: WRAP FACTOR, C_w (RUBBER-SURFACED BELT)

		Automatic Take-up		Manual take-up	
Type of pulley drive	Wrap angle	Bare pulley	Lagged pulley	Bare pulley	Lagged pulley
Single, no snub	180^o	0.84	0.50	1.2	0.8
Single with snub	200^o	0.72	0.42	1.0	0.7
	210^o	0.66	0.38	1.0	0.7
	220^o	0.62	0.35	0.9	0.6
	240^o	0.54	0.30	0.8	0.6
Dual	380^o	0.23	0.11	0.5	0.3
	420^o	0.18	0.08	-	-

Therefore, $T\text{-}_p$= 400 + 450 = 950 lbs = 425 kg (approx.)

T_{am} = 2.8755 *10 $^{-4}$ *Q*(V–V_{o-})

= 2.8755 *10 $^{-4}$ *1250*(638– 0 _)

= 230 lbs

Q = tph

V = design belt speed, fpm

Vo = initial velocity of material as it is fed onto belt, fpm

T_{ac} = total of the tensions from conveyor accessories, lbs:

$T_{ac} = T_{sb} + T_{pl} + T_{tr} + T_{bc}$

T_{sb}– From skirtboard friction = 0

The force required to overcome skirtboard friction is normally larger per foot of skirtboarded conveyor than the force to move the loaded belt over the idlers.

$T_{sb} = L_{b\,*}(C_s h_s^{\,2} + 6)$

where:

Lb = skirtboard length, ft one skirtboard

dm = apparent density of the material, lbs/cu ft

hs = depth of the material touching the skirtboard, in

3.1.2. Elevation difference, lift

H_1 = 387 m –396 m = –9 m = –29.53 ft

H_2 = 391 m –387 m = 4 m = 13.12 ft

H_3 = 407 m –391 m =16 m=52.5ft

3.1.3. Pipe shaping losses, C_{-f}

These are additional energy losses associated with changing the belt from flat to circular. These values are generally presented as a function of pipe diameter.

Assuming 50% efficiency of drive,

Total power require = 20230/.5 = 40460kW

The horsepower, hp, required at the drive of a belt conveyor, is derived from the pounds of the effective tension, Te required at the drive pulley to propel or restrain the loaded conveyor at the design velocity of the belt V, in fpm

3.2. DRIVE PULLEY RELATIONSHIPS

Dual drives based on ideal distribution between primary and secondary drive:

- For wet belts and smooth lagging, use bare pulley factor
- For wet belts and grooved lagging, use lagged pulley factor
- If wrap is unknown, assume the following:

Type of drive	Assumed wrap
• Single-no snub	180°
• Single-with snub	210°
• Dual	380°

Dual-pulley drive on return run; regenerative.

Taking wrap angle = 420*

C_w= 0.18, for bared pulley (Table 10)

Therefore, minimum tension required to prevent slippage of belt on slack side, i.e. $T_2 = T_{e*}C_w$

Dual value based on ideal distribution between primary and secondary drive.

For wet bulb and smooth lagging, use bare pulley factor.

For wet bulb and grooved lagging, used lagged pulley factor.

If wrap is unknown, assume the following

Overview of structural support:

The types of structures used to support the elevated technological conveyor structure are shown in the Fig.10, the structures are typically denoted as:

- Dog house
- Open box gantry
- Partially closed box gantry
- Totally enclosed box gantry
- Concrete gantry

4. Cost evaluation of pipe conveyor

Let us put into prospective the effect of the structural support on the overall cost of a conveyor system. To do this we will evaluate three different conveyor lengths commonly found in materials handling plants today, these being 200m, 500m and 1000m centers. Overland structures also play an important part of this paper and will be included later. For each of these belt lengths the mechanical equipment cost per meter, (not affected by the support used), is indicated in Table 12.

4.1. Belt conveying system cost galculation

The total pipe belt conveyor system cost Rs.451 crores (including training needs, testing and handing over with management clause, spare item supply guarantee clause, warranty clause and MTTF (mean time to failure) of the major repairable and non-repairable OEM items. However this excludes the cost of fine tuning of the routing which can be achieved by detailed survey. The management will do well to engage a responsible and experienced 3rd party to set the terms of the tender and ordering negotiations. It is also advisable to engage a 3rd party to oversee and certify the constructions particularly during the construction over river beds and road crossings, and testing/ operation stage before it acquires the knowledge run the system efficiently.

Fig.8 Elevation profile of first pipe conveyor section

Fig.9 Elevation profile of second pipe conveyor section

Fig.10 Elevation profile of third pipe conveyor section

4.2. Operating cost

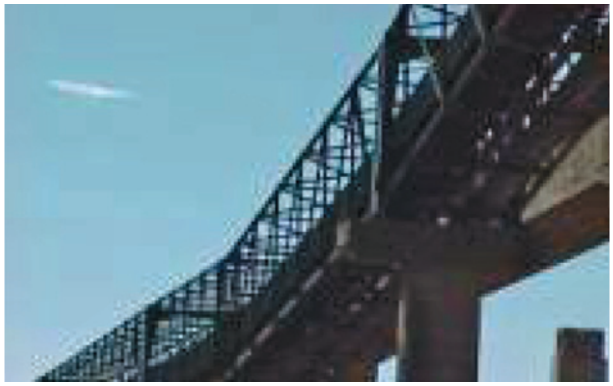
The annual operating cost of the belt conveyor system will be Rs.45.00 crores. Converted to operating cost per tonne it will be Rs.75.00 per tonne.

4.3. Application of Recommended Global Trends

For a 15.2 km long curved path belt conveying system certain basic understanding of the global trends are important.

- Speed: 2m-6m per sec (average in India: 4m/sec).
- Should have maintenance cars along the conveyor line
- Soft start/soft stop control
- Sole belt weight is 55-70kg per m.
- Motor controller: Fluid coupling or variable frequency drive

Typical “Dog House” structure



Typical “Open Box Gantry” structure

Typical “Partially Closed Box Gantry” structure

Typical “Totally Enclosed Box Gantry” structure

Typical “Concrete Gantry” structure

Typical “Triangular Gantry” structure

Fig.11 Different type of structure

While fluid coupling based conveyor load control has been trademark in such applications, today variable frequency drives are becoming popular, more because of energy saving as well rising mechatronic applications in belt conveying. A variable frequency drive (VFD) is a type of motor controller that is increasingly being used in conveyors that will have high load swings. The controller drives an electric motor by varying the frequency and voltage supplied to the electric motor. Other names for a VFD are variable speed drive, adjustable speed drive, adjustable frequency drive, AC drive, microdrive, and inverter. Frequency (or hertz) is directly related to the motor’s speed (RPMs). In other words, the faster the frequency is, the faster the RPMs go. If an application does not require an electric motor to run at full speed, the VFD can be used to bring down the frequency and voltage to meet the requirements of the electric motor’s load. As the application’s motor speed requirements change, the VFD can simply turn up or down the motor speed to meet the speed requirement.

TABLE 12: ESTIMATED COST OF TECHNOLOGICAL STRUCTURE AND MECHANICAL EQUIPMENT 1200MM WIDE 1000TPH 3M/SEC 20M LIFT

Description	Unit cost (Rs/m)
Idlers	36370
Pulleys	15200
Drive	23500
Belting	100900
Belt cleaning	830
Technological structure	32100
Take up	16750
Chutes and liners	3510
Total cost/m	229160

TABLE 13: CONVEYOR COST CALCULATION

Conveyor number	Cost calculation	Cost (crores of Rupees) excluding land acquisition cost	Remark
1	230640*2900	67	Two km of cultivated land
2	230640*7600 +230640*1000	197	Site preparation cost at hilly region is included
3	230640*4600 +230640*500	117	Site preparation cost at loose/ wet Auranga river region is included
Total conveyor cost		381 crores	Excluding land acquisition cost

*Conveyor Capital cost is based on as defined by CEMA.

NB. The above cost is inclusive of section transfer points, Silos/Bins loading and unloading, loading and unloading controls, minor stockpiles, etc.

4.4. TODAY VFD DRIVES ARE PREFERRED TO FLUID COUPLING IN BELT CONVEYING BECAUSE OF THE FOLLOWING

Drive slip energy recovery can equate to in power savings that may exceed NPV capital cost of equipment. Complexity of electronics vs complexity of fluid (seals, cooling,), possibly one electronic device is used in lieu of many fluid coupling devices. Optimal selection of starting control and stopping control tailored to conveyor geometry that may increase the belt strength and supporting structural requirements. VFDs have ability to multiplex motor control electronics resulting in a big capital savings. Ability to start many drives from one control device. Inverters (VFD) offer special load sharing methods that can be implemented on complex conveyor geometries with electronics that are not possible with fluid couplings such as modern conveyors with difficult terrain and use of horizontal curves. This can strongly influence civil (cut and fill) and structural engineering. In some instances, the conveyor would not be financially feasible with a fluid coupling.

TABLE 14: MISCELLANEOUS COST FOR THE PIPE BELT CONVEYOR

	Description	Cost (crores of rupees)	Comments
1	Control room	30.00	Real time belt conveyor operating and maintenance control, etc.
2	Maintenance machinery and workshop	20.00	Splicing, vulcanizing set up and belt, roller and drive repairing
3	Administrative buildings	3.00	
4	Sub-station	7.00	With power backups
5	Ground Protection, lighting	4.00	
6	Miscellaneous	6.00	Security and others
7	Total	70.00	

NB: It is important to ask for training needs, testing and transfer clause, guarantees and warranty if the total belt conveyor is to be run efficiently.

Disclaimer: The above calculation is an estimation. It does not include abrupt price escalations due to restrictions in supply and currency fluctuations. The calculation should be + 20% accurate. The cost does not include cost of acquisition of any item other than the parts in the conveying system and delay, etc. Generally, in such a project per day delay will be 0.25–1% per month of the investment already made at any time, depending on idling cost, depreciation, cost of capital, manpower cost and contract penalties, etc.

TABLE 15: LAND AQUISTION REQUIRED

Conveyor section	Length(m)	Width(m)	Area(m^2)
1	2900	7	20300
2	7600	7	53200
	346007		32200
	105700 (10.57 hectare)		

TABLE 16: APPROVALS FOR LAND ACQUISITION REQUIRED FROM THE CONCERNED AUTHORITIES

	Land type	Area (m^2)	Approvals
1	Forest	93800	Ministry of Environment and Forest, State Government, Office of District Land and Revenue, etc.
2	Private	338800	State Government, Office of District Land & Revenue, etc.
3	Road crossing	At NH75 15-18ft wide for pipe conveyor	NHAI, State Highway Authority, etc.

Fluid coupling does offer an advantage in trouble shooting simple conveyors. Many users who prefer simplicity and do not have necessary electronic component field support. Fluid couplings offer a mechanical overland protection one can argue is more fail-safe than VFDs. However, there are many other problems one can also list associated from fluid coupling seal and bearing failures, wrong fluid fill levels being applied, problems with the coupling being too strong for the conveyor, imbalance of coupling halves, etc. VFD's, in general, need a special protective environment to maintain the health of the electronics against temperature extremes, moisture and dust. More so than the fluid coupling.

4.5. Arguments for the use of VFD drives on conveyor drives instead of fluid couplings

1. Full speed savings in power and power factor that reduces the loss within the VFD and motor (totaling < 1%) compared to the ~3% loss in the fluid coupling and motor under full load. Then there are the control room cooling and air-conditioning that take another 1% or more plus the capital cost. However, then we can also claim the FC has its problems of bearings, seals and fluid related controls. Then there are claims the VFD motors cannot take the heat without auxiliary cooling for long starting ramps –> 100 seconds.
2. Using variable speed to match tonnage and speed to provide more-or-less constant belt cross-sectional loading can produce substantial power savings, depending on the frequencies of operating speeds - operated at 6 m/s or 4.5 m/s (best speeds to avoid amplified belt vibrations). Setting the values and savings are also dependent on the belt rubber compound. Some belts are better over the operating strain range.
3. Ability to inspect and positon belt for various damages, wear and repair.
4. Ability to identify belt critical vibration modes and enable programming the belt speed to avoid modal frequencies and operating in their bands.
5. VFD does not change with changes in temperature, with one FC drive exposed to sun while other is in the shade resulting in imbalanced demand power.
6. VFD can be designed to eliminate its operation (switched out of power path) when belt is at full speed - improving the mean-time-to-fail and mean-time-to-repair.
7. VFD can have an on-line backup power module while FC cannot thereby improve availability of larger system.
8. VFD offers better control of belt tensions and safety factor thereby improving splice life - among the techniques are special starting curves that also include using inverter frequency to monitor the health of the starting curve.
9. VFD can be set to control on speed or torque which comes in handy with multiple drives on overland conveyors.
10. VFD shows belt wear improves when operating below highest speed.
11. VFD shows better dust emissions when operating below maximum design speed.
12. VFD will show benefits in tuning our critical vibrations on overland or long belts by minimizing the belt edge flap that are instrumental in reducing idler life, in causing end disk failure in rollers, in failure of idler bracket weldments.
13. VFD can minimize belt noise by tuning out high belt edge flap rhythmic air pulsations that neighbours object to.

But before preferring VFD over fluid coupling for belt control one should ask from the vendor the followings:

a. To reduce repair time (MTTR) by having trouble shooting displayed in electronic form versus having to make site inspections of mechanical components: what should be the preferred options.
b. To impart knowledge to the end user's maintenance crew and access to regional support.
c. Engineers misapplication and/or misunderstanding of the needs of each system may be reduced by asking the vendor to run the system for a year for better understanding.
d. Load sharing complexities – drive systems do not need to be matched to motor sizes with inverters but must be matched with fluid couplings.
e. Ability to move and spot belt repairs to a designated location.
f. Electronics (manufacturers) support to be mandated for many (>15) years of service due to technical/ manufacturing advancements in components.
g. Understanding the advantages and disadvantages of very fact electronic regulation of the inverter must be understood by the designer and the supplier, especially when using multiple drives on one conveyor. Too often, the supplier does not understand the belt conveyor's elastic memory and subsequently does not understand how to properly tune the equipment. This leads to end user complaints about the equipment that should be directed at the designer and supplier's lack of knowledge, not the equipment's function.
h. There is the need to ground the motors bearing assembly when using an inverter.

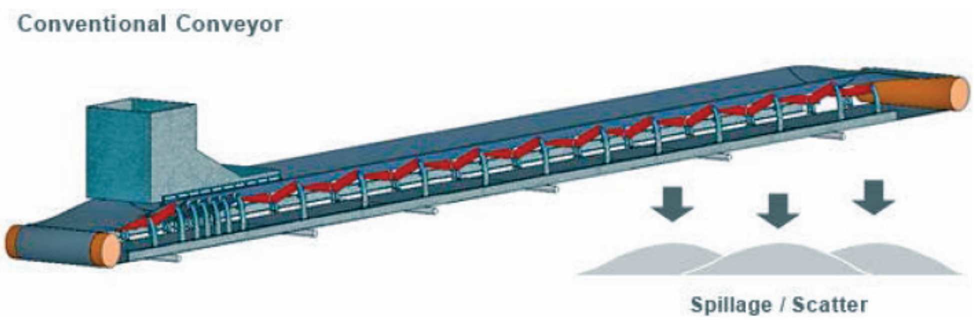


Fig.12 Loading point of conventional conveyor

13.1. Other details

The loading section

The feeding or loading section of a pipe conveyor is similar to that of a conventional belt conveyor. To eliminate the problem of material spillage as associated with troughed belt conveyors the pipe conveyor feed zone incorporates a specially designed skirt board for effective sealing with low friction impact slider pads. A quick release mechanism enables impact rollers to be lowered for removal even with a moving belt and facilitates ease of maintenance. Transitional idlers from the impact zone to the pipe form, comprise a series of troughing idlers of varying and adjustable troughing angles. A single guide roller is used to press one edge of the belt below the other as the belt comes together. This idler is installed just ahead of the first circular arranged idler set. This idler eliminates belt edge abrasion and allows proper overlap closing of the belt.

Uniform feed to the pipe conveyor is important in a pipe conveyor for its stability and tracking. Use of belt or vibrating feeders ensure a constant and uniform flow.

13.2. Intermediate and tubular section

The intermediate section of the pipe conveyor is the part where the belt is made to roll into a tubular shape. This is achieved by causing the belt to pass through a set of six idlers arranged in a circle each for the carrying and return run.

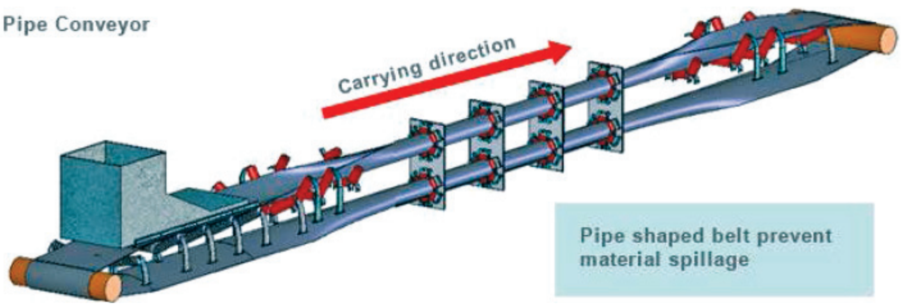


Fig.13 Loading point of pipe conveyor

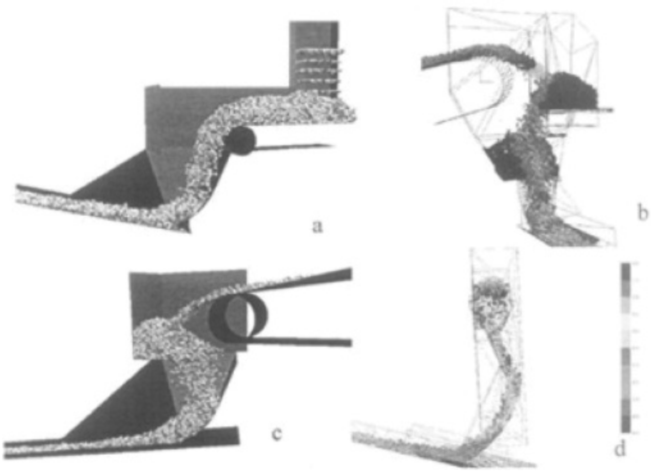


Fig.14: Intermediate transfer section

With the pipe conveyor belt guided by idlers surrounding the belt on all sides, the conveyor is able to negotiate curves and centerline misalignments. To ensure that the belt overlap is located as near the top of the belt on the carrying side, a few set of training idlers are provided with adjustable bottom rollers.

Assisting most in belt stability and also keeping the overlap near the center position is of course the weight of material conveyed in the pipe and its heavy center of gravity on the lower cross-section of the belt. On the return side where the overlap is on the bottom of the pipe shape, the extra weight of the overlap maintains dynamic stability of the belt.

13.3. The discharge end and drive

The discharge of the pipe conveyor is similar to that of conventional belt conveyors. The belt in the tubular form is allowed to gradually take the trough shape by a series of idlers of varying troughing angles. Material is discharged over the head pulley.

Drive motors are usually squirrel cage and equipped with VVVF AC drives. This modern drive ensures smooth starting, allows for step less belt speed variation to create the desirable belt load cross-section suitable for the application and maintains belt stability.

13.4. Belt Selection Considerations

In selecting a conveyor belt for a specific duty consideration is given as in the followings:

(a) Tensile strength

The maximum belt tension calculated by the method outlined above should be matched by the rated belt tensions for the type of joint to be used.

Maximum tension in all three belt = 2114kN,

Belt width = 1.27 m

So tensile strength = 2908/1.27 = 2290kN/m = 2290N/mm

So, belt specification ST-2500 (Table 17)

(b) Number of plies for load support

The minimum number of plies (fabric belting) required for adequate load support must be determined by relating the belt width to the density of the material to be conveyed.

(c) Minimum pulley diameters

If the size of pulleys is already determined, the belt construction, provisionally selected from the previous considerations can be checked against the relevant pulley diameters for suitability. Conversely, for a new installation, the minimum recommended pulley diameters can be quoted.

(d) Gauge of covers required

The correct gauge of cover is necessary to give protection to the belt carcass from material impact and wear must be

Table 17: General steel cord belt

Belt type	ST-2250	ST-2500	ST-2800	ST-3150	ST-3500	ST-4000	ST-4500	ST-5000	ST-5400
Tensile strength (N/mm)	2250	2500	2800	3150	3500	4000	4500	5000	5400
Steel cord construction			K7*7			K7*19			
Thickness of top cover (mm)	8	8	8	8	8	8	8	8.5	9
Thickness of bottom cover (mm)	6	6	6	8	8	8	8	8.5	9
Belt weight (kg/m^2)	31	34	35.5	39.5	41	43.5	46	49.5	53.5
Drive pulley, take-up pulley, Snubs pulley (mm)	1400	1500	1550	1700	1800	1850	2000	2100	2400
	1200	1200	1250	1350	1400	1400	1600	1700	1900
	800	900	950	1000	1050	1050	1200	1250	1400
Working tensile KN/M SF=7	320	355	400	450	500	570	645	715	770

determined by relating the belt to the size and density of the material to be handled.

13.5. Idlers

13.5.1. Functional description

An endless conveyor belt in a conveyor structure is dragged from the tail pulley where material is loaded onto the conveyor, to the head pulley or drive pulley where the material is discharged. Between a conveyors' tail and head pulleys, whether the distance is a number of kilometers or merely a few meters, the carrying and return strand belting is supported on idler sets. There are two basic types of conveyor idler sets namely.

13.5.2. Requirement of an Idler

To support the load of material and belt throughout its length.

- Considerations in selection
- Diameter of roll
- Diameter of shaft
- Geometry of idler set
- Construction of shell
- Seal configuration
- Idler set life
- Power absorbed

14. Design factors

Diameter of roll and shaft are inter-related in calculating an optimum idler design, because they directly affect the bearing life. Therefore the initial criteria for selection will be:

- Roll diameter
- Bearing life

A. Shaft deflection

B. Roll diameter

The roll diameter has been generally ignored as the criteria for idler selection, where the standard 127 mm diameter roll is used for most applications

Table 18: Idler bearing type

Idler bearing details			
Shaft Diameter (mm)	Bearing type	Dynamic bearing rating (N)	Wear rating (N)
20	6204	12700	28000
25	6205	14000	28000
25	6305	22500	28000
25	420205	0	28000
30	6206	19500	0
30	6306	28100	0
30	420306	0	0
35	6307	33200	0
40	6308	41000	0
50	6310	61800	0
60	6312	81900	0

Roll diameter = 4 inch = 102 mm

C. Bearing life

Bearing life has two common methods of calculation: Firstly the L10 selection formula

$$L_{10} = \frac{(C/P)^e \times 10^6}{60 \times N}$$

L10 = Calculated life (hours)

C = Bearing dynamic load factor (N)

From Table 19: For idler bearing dia = 1 inch = 25 mm, C = 22500 N

e = 3.0 for ball bearings, 10/3 for roller bearings

P = Radial load on the roll (N) =3810 N

N = Bearing rotating speed (r.p.m.) = 60*v*(3.1416*D)

= 60*3.25*3.1416*0.1

= 60 rpm

v = Belt speed (m/s) = 3.25 m/s

D = Roll diameter (m) =0.1 m

L10 = $(22500/3810)^{10/3}$ * $(10^{6/}(60*N))$

= 103408 hours

S.K.F. (U.K.) in conjunction with the British National Coal Board have published an empirically determined formula for calculating the effective service life (wear life) of its seize resistant bearings, as follows:

Les= (Lp*Sef*Ef)/Uf

where

Les = Effective service life (years)

Lp = Bearing life, initial stage prediction (years)

= (RW/(P/2)) $^{2.5}$/(0.522*N)

Rw = Bearing wear rating (N) = 28000 N

P = Load on the roll (N) = 2810 N

N = Bearing rotating speed (r.p.m.) = 60 rpm

Therefore

Lp = (28000/(3810/2)) $^{2.5}$/(0.522* N)

= 26.4 years

Uf = Usage factor = 0.8

Ef = Environmental factor = 0.77

Sef = Seal efficiency factor = 0.75

Les = (26.4*0.75*0.77)/0.8

=19 years

TABLE 19: SEF (SEAL EFFICIENCY FACTOR)

0.75	Most efficient sealing condition
0.65	High torque contact seal
0.60	Extended labrynth seal
0.50	For shaft deflection >0.004 radians (13.75min)
0.40	Seals with grease churning action

TABLE 20: EF (ENVIRONMENTAL FACTOR)

0.11	Conveyors subjected to occasional flooding and concentrated dust – underground mines
0.95	Conveyors subjected to concentrated dust and rainfall – plant conveyors
0.77	Conveyors subjected to natural countryside dust and rainfall – overland conveyors

TABLE 21: UF (USAGE FACTOR)

1.0	24 hours per day
0.7	12 hours per day
0.5	6 hours per day

Conclusions

The final selection of the pipe belt conveyor so important, yet fraught with so many challenges to decide, is very critical to the financial success of a project. In the paper we did not consider the pilferage, sudden power breakdown, vandalism, etc – all contributing to the project cost. But we have prepared a cost and its breakup that would be helpful, if not anything else, a starting point of calculation.

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Summary

Utilization	Basis– 300 days/year, 20 hr/day	
Material	Coal (–100mm) @ over 50PCF	
Pipe diameter	400mm	
Capacity	1250te/hr	
Conveyor speed	3.25m/s	
Length of conveyor	15.2 km	
Idler class	CEMA C6	
Idler size	4 inch (102mm) Diameter (High performance)	
Idler bearing dia	1 inch (25.4mm) Diameter	
Idler spacing	Straight	6 feet
Overall lift	–9m, 4m, 16m	
Transition distance	10.5m	
Belt specification	ST-2500, K7*19	
Various pulley size	Drive pulley	1500mm
	Take-up pulley	1200mm
	Snubs pulley	900mm
Belt weight	34 kg/m^2	
Conveyor cost	Capital cost	Rs.381 Crores
	Operating cost	Rs.75 per tonne
	Land acquisition required	10.57 Hactares
Miscellaneous cost	Rs.70 Crores	
Installed power required	40460 kW	

References and recommended reading

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