veyors, lightweight truss sections are used that permit longer spans between supporting legs, and economical structural cost. A decking is provided to allow return run of the belt which also lends lateral rigidity to the structure. For long centre conveyors, sidewalk ways are provided for inspection and adjustment to idlers. The structures are often covered by tin plate at the top and sides to protect the materials being conveyed under the sky outside the plant. Fig. 6.1.11 shows photographs of two long centre conveyors with their covered structures, side walks etc.

Fig. 6.1.11. Photographs of long centre conveyors with their structures

(*j*) **Transfer terminals:** In a long-centre conveyor, direction of the conveyor is changed in a transfer terminal where materials from one conveyor is transferred into another conveyor. The second conveyor is laid out at certain angle (generally 90°) to the first one. The discharge from first conveyor takes place at a higher point, and materials is directed to the second conveyor situated at a lower height, through properly shaped and sized transfer chute. This transfer is a critical operation. The transfer terminal is enclosed within a structural framework, covered in all sides, called a junction tower.

6.1.5 Aspects of Belt Conveyor Design

The major points in selection and design of a belt conveyor are:

(*a*) Checking/determining capacity of a conveyor.

(*b*) Calculating maximum belt tension required to convey the load and selection of belt.

(*c*) Selection of driving pulley.

(*d*) Determining motor power.

(*e*) Selection of idlers and its spacing.

Above points have been discussed below in respect of flat as well as troughed belt conveyor. Necessary references have been made to IS 11592:2000 which provides guidance for selection and design practices to be followed for belt conveyors of sizes ranging from 300 mm to 2000 mm width of belt.

(*a*) **Checking/Determining Conveyor Capacity**

This basically means to check at what rate (tons/hrs. or units/min) a belt conveyor of a given belt width and speed can convey a particular bulk material or unit loads. Conversely, it is to find out the size and speed of the conveyor to achieve a given conveying rate.

Belt Width: (*i*) On a flat belt, free flowing materials will assume the shape of an isosceles triangle (Fig. 6.1.12 [*a*]). The angle of dynamic repose "φ_1" may be considered to be equal to 0.35φ, where "φ" is the static angle of repose for the material. To avoid spillage, the belt width "B" is taken at least 25% more than the base of triangle "*b*". Thus $b = 0.8B$. As per table 7 and 8 of IS 11592, $b = 0.9B - 0.05$ m for $B \le 2$ m. Therefore, the assumption $b = 0.8B$ is more conservative for B > 500 mm.

Referring to Fig. 6.1.12(*a*), the cross sectional area of the load on a flat belt is :

$$F_1 = \frac{bh}{2} = \frac{1}{2}\ (0.8B \times 0.4B \tan\varphi_1) = 0.16B^2 \tan(.35\varphi) \qquad ...(i)$$

Therefore, the conveying capacity "Q_f" of a flat belt conveyor is given by

$$Q_f = 3600F_1 \times V \times \gamma = 576B^2\, V\gamma \tan(0.35\varphi),\ \text{tons / hr} \qquad ...(ii)$$

where,

γ = bulk density of material in tons /m^3, and

V = velocity of belt in m/sec.

B = Belt width in metres.

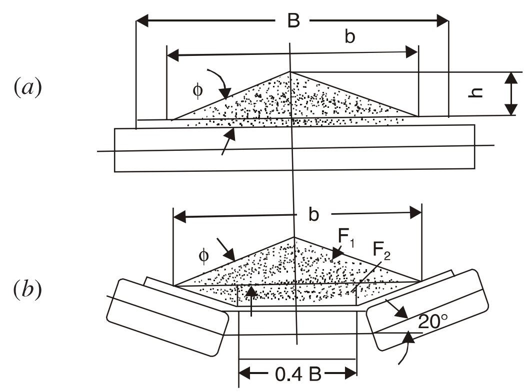

Fig. 6.1.12. Bulk load on flat and troughed belt conveyor

(*ii*) For a three roller troughed belt conveyor (Fig. 6.1.12 [*b*]), where the length of the carrier rollers are equal, the length of each roller l_r can be taken as a $l_r = 0.4B$. Let the trough angle be "λ". Then, cross sectional area of the load, $F = F_1 + F_2$.

The trapezoidal area

$$F_2 = \frac{1}{2}(0.4B + 0.8B) \times 0.2B \tan\lambda = 0.12B^2 \tan\lambda \qquad ...(iii)$$

This is based on the assumption that the base "*b*" of top triangular area is given by $b = 0.8B$, as considered in (*i*) earlier.

$$\therefore \qquad F = 0.16B^2 \tan(.35\varphi) + 0.12B^2 \tan\lambda = B^2[0.16 \tan(.35\varphi) + 0.12 \tan\lambda]$$

The conveying capacity "Q_{tr}" of the troughed conveyor is

$$3600FVv = B^2Vv\,[576 \tan(.35\varphi) + 432 \tan\lambda],\ \text{tons/hr} \qquad ...(iv)$$

(*iii*) In case of flat belt carrying unit (box shaped) load the belt width B is taken to be ≅ width of the load + 200 mm. The capacity of the conveyor in terms of number of unit loads conveyed per unit time depends on orientation of unit loads on belt and speed of belt. Orientation of load depends on strength of the belt to carry unit load as well as on stability of the load on conveyor. This can be explained by an example given below.

Example:

Boxes of size 220 mm × 180 mm × 100 mm have to be conveyed by a belt conveyor of sufficient belt strength, at the rate of 2000 boxes per hour. What will be the size and speed of the conveyor?

Solution:

For stability, the boxes should be conveyed with their 100mm side as height. For safe conveying of boxes without moving off the belt, the belt width should be suitable for conveying the boxes with 220 mm side as width on the belt. So belt width should be 220 + 2 × 100 = 420 mm or its nearest higher standard size. With 420 mm belt width, even the maximum corner dimension of the box $\sqrt{220^2 + 180^2}$ = 284 mm will leave a side clearance of $\frac{1}{2}$ (420 – 284) = 68 mm. As per IS 1891:1994 (part I), the next higher standard size of 500 mm wide belt is chosen.

If the boxes are placed with a gap of say 200 mm between two boxes, then the maximum speed of conveyor "V" = $\frac{2000 \times (180 + 200)}{60 \times 1000}$ =12.67 m/min, which is quite a low speed for a 500 mm belt conveyor, hence acceptable.

In this problem, it is to be noted that, delivery of 2000 boxes per hour means same number of boxes to be loaded also *i.e.*, at a rate of $\frac{3600}{2000}$ =1.8 seconds per box. This may not be possible by manual loading and some type of automatic loading device needs to be incorporated.

IS: 11592:2000 has detailed out the maximum sectional area of materials on flat, two roller troughed and triple roller troughed belts for different belt widths, surcharge angles (dynamic angle of repose) and trough angles. These data may be interpolated for intermediate values of trough angles and dynamic angle of repose for different bulk materials as specified in IS:8730.

Belt Speed: Recommended belt speed depends on the width of the belt as well as lump size factor of the bulk material, its air borne factor and also its abrasiveness factor. IS: 11592:2000 gives the maximum recommended belt speeds for different sizes of belts based on "speed factor" (speed factor = lump size factor + air borne factor + abrasiveness factor). Tables 6.1.2 and 6.1.3 give the above factors and Table 6.1.4 shows the recommended maximum belt speeds. Higher belt speeds may be considered under special design conditions only.

Table 6.1.2. Lump size factor

Material	Lump Size	Lump Size Factor	Air Borne Factor
Fine Grain to Dust	< 10 mm	0	4
Granular	< 25 mm	1	0
Sized and Unsized	Quantity of largest lump is < 20 per cent of maximum permissible lump size (for the selected belt width)	2	0
Sized	Quantity of largest lump is < 60 per cent of maximum permissible lump size (for the selected belt width)	3	0
Unsized	Largest lump does not exceed maximum permissible lump size (for the selected belt width)	4	0

Table 6.1.3. Abrasiveness Factor

Abrasiveness	Type of Material	Abrasiveness Factor
Non Abrasive	Free flowing materials, such as cereal grains, wood, chips, wood pulp, fullers earth, flue dust, soda lime, char, loam sand, ground gravel.	1
Mildly Abrasive	Materials, such as aggregate, run-of-bank sand and gravel, slate, coal, salt, sand stone.	2
Abrasive	Materials, such as slag, spar, limestone concentrates, pellets.	3
Very Abrasive	Iron ores, taconite, jaspar, heavy minerals, flint rock, glass cullet, granite, traprock, pyrites, sinter, coke etc.	4

Table 6.1.4. Maximum Recommended Belt Speeds (m/s)

Speed Factor \ Belt Width, mm	Upto 500	600 to 650	750 to 800	950 to 1050	1200 to 2000
1	2.50	3.00	3.50	4.00	4.50
2	2.30	2.75	3.20	3.65	4.12
3-4	2.00	2.38	2.75	3.15	3.55
5-6	1.65	2.00	2.35	2.65	3.00
7-8	1.45	1.75	2.05	2.35	2.62

For a conveyor sloping up (ascending), a slope factor 'k' is multiplied with the calculated conveyor capacity to get the actual capacity. The 'k' factors with angle of inclination is given in following table:

Degrees	0-2	4	6	8	10	12	14	16	18	20
‘k’ factor	1	0.99	0.98	0.97	0.95	0.93	0.91	0.89	0.85	0.81

(*b*) **Belt Tension**

In belt conveyor, the motive force to draw the belt with load is transmitted to the belt by friction between the belt and the driving pulley rotated by an electric motor.

From Euler's law of friction drive, considering no slip between the belt and pulley,

$$\frac{T_1}{T_2} = e^{\mu\alpha}, \quad ...(v)$$

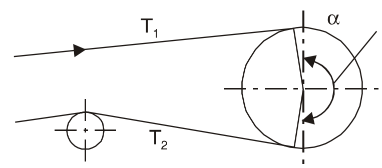

Fig. 6.1.13. Tensile forces on belt

where, T_1 = Belt tension at tighter side

T_2 = Belt tension at slack side

α = Wrap angle in radian

μ = Coefficient of friction between pulley and belt

$T_1 - T_2$ = “T_e” is the effective pull in the belt which is pulling the loaded belt against all resistances against the belt movement.

From eqn.(*v*), $T_e = T_1 - T_2 = T_2(e^{\mu\alpha} - 1)$ ...(*vi*)

Estimation of effective pull T_e: “T_e” is the sum total of all the resistive forces against the motion of belt carrying the load. The various components of resistances are as under:

Main resistance “R” comprising of :

(*i*) The resistance force caused by rolling friction in the bearings and seals of the carrying and return idlers.

(*ii*) The belt advancement resistance caused due to sagging of belt between idlers. *i.e.* due to recurrent flexing of belt and material over idlers.

Secondary resistance “R_s” comprising of :

(*i*) The inertial and frictional resistances R_a due to the acceleration and friction of the material at loading area.

(*ii*) The force R_w required for bending (or wrapping) of the belt over pulleys.

(*iii*) Resistance R_{ska} due to sliding friction between belt and side walls of the skirt at loading area.

(*iv*) Bearing resistance R_b of pulleys (with the exception of driving pulley, which is overcome directly by driving motor).

Special main resistance “R_{sp1}” comprising of:

(*i*) Drag due to forward tilt of idlers.

Special secondary resistance “R_{sp2}” comprising of:

(*i*) Resistance from belt cleaners.

(*ii*) Resistance from discharge ploughs and belt trippers.

Slope resistance “R_{sl}”, which is the vertical component of the loaded belt when the conveyor is inclined to horizontal by an angle “δ”.

Thus effective pull "T_e" can be written as:

$$T_e = fLg\{m_c + m_r + (2m_b + m_G)\cos\delta\} + R_s + R_{sp1} + R_{sp2} + m_G gL\sin\delta \quad ...(vii)$$

where f = artificial coefficient of friction taking care of rolling resistance of idlers and belt advancement resistance.

The value of 'f' = 0.02 for horizontal belt conveyor.

= 0.012 for a down hill conveyor requiring a brake motor.

L = length of the conveyor, m.

m_c = moving mass of carrying idlers per metre, kg/m.

m_r = moving mass of return idlers per metre, kg/m.

m_b = mass of belt per meter, kg/m.

m_G = mass of load per metre of belt length, kg/m.

δ = angle of inclination.

L Sin δ = lift of conveyor between loading and discharge point.

Calculation of secondary resistance is based on, $R_s = R_a + R_w + R_{ska} + R_b$

where, R_a is inertial and frictional resistance of material at loading area.

$$= Q \times 1000 \times \rho(V - V_0) \quad ...(viii),$$

where Q = Volumetric conveyor capacity, m^3/s.

ρ = bulk density, tonnes/m^3.

V = vel. of belt, m/sec.

V_0 = vel. of material at the point of loading, m/sec.

R_w is wrapping resistance between belt and pulley, generally calculated from the formula.

$$R_w = 9B\left[140 + 0.01\frac{Tav}{B}\right]\frac{t}{D} \quad ...(ix)$$

for fabric carcass belt, or

$$R_w = 12B\left[200 + 0.1\frac{Tav}{B}\right]\frac{t}{D} \quad ...(x)$$

For steel cord belt.

where, $T_{av} = \dfrac{T_1 + T_2}{2}$, Newton

t = belt Thickness, mm

D = pulley dia., mm

B = belt width, m

However, the wrapping force is approximated as a percentage of maximum belt tensions on tight and slack side. Following values of R_w may be assumed as a thumb rule.

Location of pulley	*Degree of wrap*	*Wrap resistance, Newton*
Tight side	150° to 240°	230
Slack side	150° to 240°	175
All other pulleys	—	140

The other resistances R_{ska} and R_b under secondary resistance and other special resistances R_{sp1} and R_{sp2}, can be calculated based on different formulae given in sections 8.5.1.3 and 8.5.1.4 of IS:11592, which are either small in values or not always applicable.

Once 'T_e' is estimated, tensions at the tight side (T_1) and slack side (T_2) are worked out using eqns. (*vi*) and (*v*).

The coefficient of friction between belt and driving pulley under different operating conditions can be in considered as given in Table 6.1.5.

Table 6.1.5. Friction Coefficient between Driving Pulley and Rubber Belting

Pulley Surface / Operating conditions	Smooth Bare Rim Steel Pulley	Rubber Lagging with Herringbone Patterned Grooves	Pulyurethane Lagging with Harringbone Patterned Grooves	Caramic Lagging with Harringbone Patterned Grooves	PVC Belt Type
Dry condition operation	0.35 to 0.4	0.4 to 0.45	0.35 to 0.4	0.4 to 0.45	0.25 to 0.35
Clean wet condition (water) operation	0.1	0.35	0.35	0.35 to 0.4	0.15 to 0.30
Operation under wet and dirty (clay or loam) conditions	0.05 to 0.1	0.25 to 0.3	0.2	0.35	Less than 0.25
Operation under very wet and dirty condition	0.05	0.25	0.2	0.3	0.15

Checking for belt sag : The minimum tensile force 'T_{min}' which should be exerted on the belt to limit belt sag between two sets of idlers is calculated by the formula:

$$T_{c\,min} \geq \frac{l_c^2 (m_b + m_G) g}{8S}, \text{ for carrying side} \quad ...(xi)$$

$$T_{r\,min} \geq \frac{l_r^2 m_b g}{8S}, \text{ for return side,} \quad ...(xii)$$

where l_c, l_r are idler spacing in meters,

and S = maximum allowable belt sag = .005 to .02 m.

If the $T_{c\,min}$ and $T_{r\,min}$ are higher than the tensions T_1 and T_2 calculated from total resistance consideration, these higher values of belt tensions should be achieved through proper belt tensioning and should be considered in calculation of different design parameters.

In order to increase the effective pull without slippage, the wrap angle of belt over driving pulley or pulleys is generally increased. Fig. 6.1.14 below shows the different drive arrangements for achieving higher value of wrap angle 'α'.

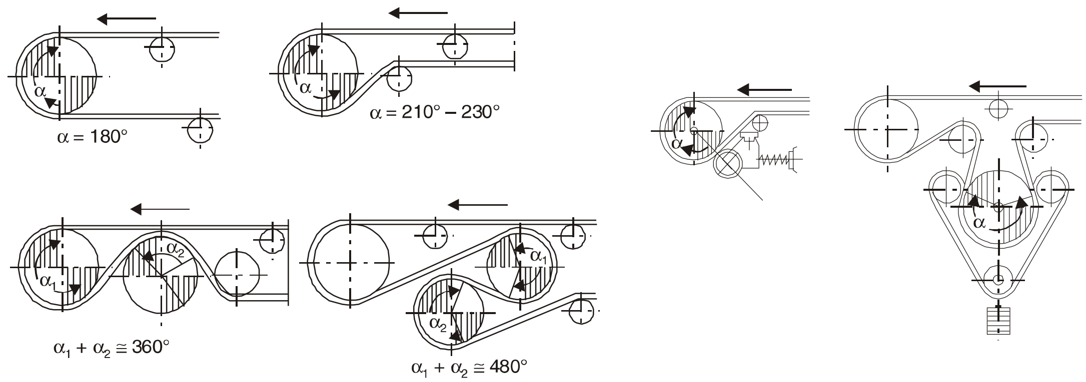

Fig. 6.1.14. Different belt drive arrangements

Selection of Belt Carcass : Maximum peripheral force "Te_{max}" often occurs when starting up the completely loaded conveyor from rest. The ratio "ξ" between Te_{max} and T_e depends on the type of drive selected, which varies from 1.8 -2.2 for direct on line start of motor connected by a pin bush type coupling, to a lower value of 1.2 for start-delta starting of a slip ring motor connected by flexible coupling or a 3 phase squirrel cage motor connected with a fluid coupling with delayed chamber filling.

Taking this maximum effective pull, $Te_{max} = \xi Te$, T_{1max} should be calculated where $T_{1max} = T_e \xi \left(\dfrac{e^{\mu a}}{e^{\mu a} - 1} \right)$. Based on this maximum tensile force in belt, the belt carcass should be selected from manufacturers' catalogues having sufficient breaking strength to withstand this maximum tensile force.

(c) **Selection of Driving and Other Pulleys**

The large diameter driving and tail end pulleys are generally fabricated from steel plates. The pulley shafts are made integral with the barrel. The barrel and journal portions are machined in one setting to make them concentric. The pulley faces are given a ''crown'' of around 0.5% of the pulley diameter, but not less than 4mm.

Diameter of pulley is selected based on the construction (number of plies which is proportional to carcass thickness) of the belt used. The recommended values of minimum pulley diameters based on carcass thickness and fibre materials is given in Indian standard IS: 1891 (part I).

However, as a thumb rule, diameter 'D' can be approximated from the relation, $D \geq ki$, where i = number of plies of belt, and k = 125 to 150for i between 2 to 6, and k = 150 for i between 8 to 12. Calculated 'D' is rounded off to the larger standard sizes of 250, 315, 400, 500, 630, 800,1000,1250,1400,1600, 1800 and 2000 mm.

The length of the barrel is kept 100mm to 200 mm more than the belt width.

The drive pulley may be covered (lagged) with a layer of suitable material like rubber, polyurethane, ceramics etc, whenever necessary, to increase the coefficient of friction between the pulley and belt. The thickness of such lagging may vary between 6 to 12 mm, and having a hardness between 55 to 65 shore A scale. However, the lagging on other pulleys like snub and bend pulleys, the hardness chosen is much less (35 to 45 shore A) to protect damage to the surface covering of the belt.

Courtesy : Sandvik Asia Ltd., India

Fig. 6.1.15. Two belt conveyors carrying ores, capacity 11,000 tph each, 13.8 km long

(*d*) **Motor Power**

The power required at the driving pulley just for driving the belt is given by the formula:

$$P_d = \frac{T_e \times V}{1000} \text{ kW, where } T_e = \text{effective tension} = (T_1 - T_2) \text{ in Newton}$$

V = belt speed, m/sec

P_d = driving power, kW

However, the actual power requirements, considering the wrap resistance between belt and driving pulley, and driving pulley bearings resistance, the actual motor power, P_A is given by

$$P_A = \frac{T_e V}{1000} + \frac{(R_{wd} + R_{bd})V}{1000} \text{ kW, where}$$

R_{wd} = wrap resistance between belt and driving pulley.

R_{bd} = driving pulley bearing resistance.

Additional power requirements should be taken into considerations for each belt tripper, and belt cleaner used with the conveyor.

The final motor power "P_M" is calculated based on efficiency "η" of the transmission system used consisting of gear box, chain / belt drive, coupling etc. Thus, $P_M = \dfrac{P_A}{\eta}$.

Actual motor is chosen with a power rating of 15% to 20% greater than the calculated power 'P_M'.

(*e*) **Selection of Idlers**

Depending on the type of belt conveyor, the carrying idlers can be troughed or straight, while the return idlers are generally always straight. The major selection criteria are the roller diameters and spacing of these idlers.

The range of idler diameters to be selected depends on belt width, maximum belt speed and type of materials to be conveyed. Based on these, the idlers are classified into following six series as specified in IS:11592:2000 and given in Table 6.1.6 below:

Table 6.1.6. Idler Classification

Idler Series	Roller Diameter	Belt Width	Maximum Belt Speed, m/s	Suitable for
I.	63.5 to 101.6	300-800	2.5	Fine material with small lumps-Nonabrasive, intermittent duty.
II.	88.9 to 139.7	400-1000	4.0	Fine material, small sized lumps, slightly abrasive, continuous duty.
III.	101.6 to 139.7	500-1200	4.0	Unsized medium lumps, mixed with fine sized small lumps, moderately abrasive, continuous duty.

IV.	127 to 139.7	500-1400	4.0	Unsized, large lumps, mixed with small sized medium lumps moderately abrasive continuous duty.
V.	139.7 to 219.1	800-2000	5.0	Large size lumps, highly abrasive, critical duty.
VI.	168.3 to 219.1	1600-2000	4.0	Large capacity conveyor with lumps.

Spacing for carrying and return idlers also depends on belt width, and bulk density of the material to be conveyed. The recommended spacing as per IS:11592:2000 is given in table 6.1.7 below.

Table 6.1.7 Recommended Idler Spacing

Belt Width	Troughed Belt		Flat Belt	Return Idler Sets
	Carrying Idler Sets for Materials of Bulk Density (t/m^3)			Troughed and Flat Belt
	0.40 to 1.20	1.20 to 2.80		-
	Recommended Spacings, mm			
300 400 500 650	1500	1200	1000	3000
800 1000	1200	1000		
1200 1400 1600 1800 2000	1000	1000	750	

6.2 CHAIN CONVEYORS

6.2.1 Definition / Description

The term chain conveyor means a group of different types of conveyors used in diverse applications, characterised by one or multiple strands of endless chains that travel entire conveyor path, driven by one or a set of sprockets at one end and supported by one or a set of sprockets on the other end. Materials to be conveyed are carried directly on the links of the chain or on specially designed elements attached to the chain. The load carrying chain is generally supported on idle sprockets or guide ways. The endless chains are kept taught by suitable chain tensioning device at the non-driven end.