CHAPTER

6.0 Conveyors

Different classes of conveyors forming the **conveyor** group is by far the most frequently used materials handling equipment primarily for conveying bulk materials in process industries and also for conveying certain types of unit loads in large quantities. Basic definition of a conveyor and its classifications have already been given in chapter 4. In the present chapter, definition / description and operational characteristics of the different classes of conveyors have been discussed. Special features and use of some of the commonly used conveyors under each of these classes have been included. Certain design aspects of a few classes of conveyors have also been touched upon.

6.1 BELT CONVEYORS

6.1.1 Definition / Description

A belt conveyor consists of an endless flat and flexible belt of sufficient strength, made of fabric, rubber, plastic, leather or metal, which is laid over two metallic flat pulleys at two ends, and driven in one direction by driving one of the two end pulleys. Material is placed on this moving belt for transportation. The active half of the belt is supported by idler rollers or slider bed. The return half of the belt may or may not be supported, as it generally does not carry any additional load other than its own weight. The endless belt is kept taught by a belt tensioning arrangement.

6.1.2 General Characteristics

(*i*) Belt conveyors operate in one vertical plane, horizontally or with an inclination (up or down) depending on the frictional property of the load conveyed.

(*ii*) For changing direction of the materials being conveyed, in the horizontal plane, more than one belt conveyors are needed.

(*iii*) Conveying capacity of a conveyor can be controlled by changing belt speed.

(*iv*) Belt conveyors are generally employed for continuous flow of materials.

(*v*) Metal/special belts can carry hot, abrasive or reactive materials.

6.1.3 Types of Belt Conveyors

(*a*) **Flat Belt Conveyor:** In this conveyor, the active side of belt remains flat supported by cylindrical rollers or flat slider bed. The conveyor is generally short in length and suitable for conveying unit loads like crates, boxes, packages, bundles etc. in manufacturing, shipping, warehousing and assembly operations. Flat belts are conveniently used for conveying parts between workstations or in an assembly line in mass production of goods. Fig. 6.1.1 shows a flat conveyor.

Fig. 6.1.1. A flat belt conveyor with drive control

(*b*) **Troughed Belt Conveyor:** In this conveyor, comparatively wide flat belt is supported on troughed carrying rollers or shaped supporting surface so that the two edges of the active side of the belt are elevated from the middle part to form a trough. This provides a greater carrying capacity than a flat belt of equal width for conveying bulk materials or those materials which would slide off flat belts. These conveyors are used in handling bulk materials of different classes. The return side of the belt is generally kept flat supported on cylindrical rollers.

The troughed conveyors which are used within a plant for moving bulk materials from one point to another, are generally termed as ''normal'' or ''transfer'' conveyors. These are comparatively of shorter lengths, and path of movements are in straight line in a horizontal or an inclined plane. The stresses in the belts being within limits of cotton fabric belts.

However, troughed belt conveyors are often used for transportation of bulk materials over long distances, by means of a series of conveyors, over paths that are combination of inclines, declines and horizontal sections, following the natural contours of the ground. These are generally termed ''long-centre'' conveyors. There is no clear demarcation between a normal or long-centre conveyor. Long center conveyors are those where belt tension is high warranting use of high tension quality belts with less belt stretch, and low acceleration through gradual starting controls for the drive. By using a number of conveyors in series, it is possible to change the direction of materials movement at the junction of two conveyors, called ''transfer terminal''.

Long-centre conveyors are used for jobs like: (*i*) transportation of the output of mines to the processing plants, (*ii*) materials from shipping ports to the storage/transport loading sites, (*iii*) materials from outdoor storage yards to inside plants, (*iv*) movement of materials between plants etc.

(*c*) **Closed Belt Conveyor:** In a closed belt conveyor, the specially fabricated belt, after being loaded with the material, can be wrapped completely around the load. It essentially forms a closed tube moving along with the material. The advantages of a closed belt conveyor are: (*i*) it can handle fragile materials safely and without breaking by reducing inter particle collision, (*ii*) it can handle fine bulk materials without being swept by air (however, it is not really air tight at loading and unloading points), (*iii*) ability to handle corrosive and reactive materials without contamination and (*iv*) the tubed belt can travel around bends in more than one plane and hence versatile in layout.

The lengths of these conveyors are generally limited. Different designs of closed belts have been manufactured and used in different countries. In the following Fig. 6.1.2, a type called Zipper Conveyor is shown. Fig. 6.1.3 shows how the belt is closed after the belt is filled up at its flat configuration. Different designs for closing two ends of the belt have been developed by different manufacturers.

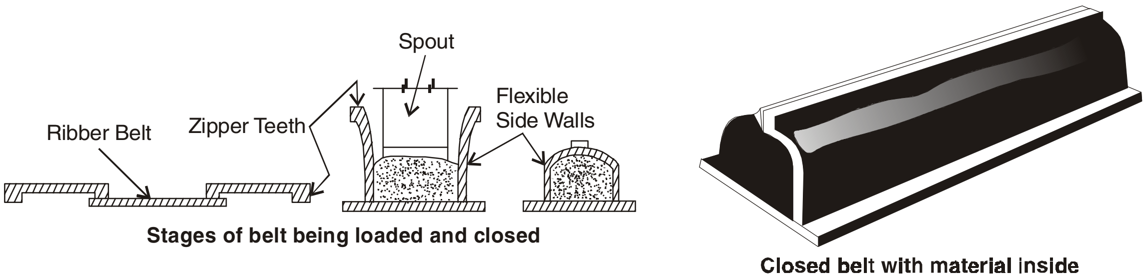

Fig. 6.1.2. Endless zipper belt

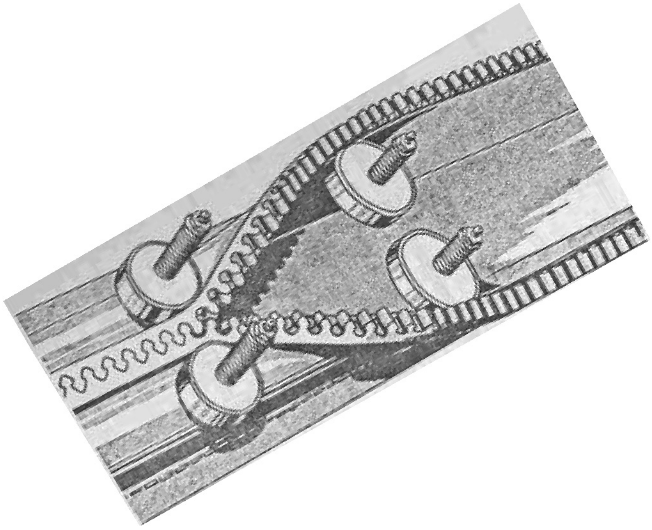

Fig. 6.1.3. Spreading, filling and locking of a closed conveyor

(*d*) **Metallic Belt Conveyor:** This is a flat belt conveyor where the flexible belt is replaced by a cold rolled carbon or stainless steel strip belt of thickness from 0.6 mm to 1.2 mm. The ends of the steel strip are lap joint riveted with a single row of special wide flat head rivets. A steel belt runs flat on cylindrical idlers or runs troughed on resilient idlers (made by suitable length of springs). Apart from all rolled strip steel belts, wire-mesh, belts of different designs have been used. The entire length is made up of short length sections. One of the designs is made up of flat wire spiral sections, shown in Fig. 6.1.4. The wire-mesh belts are more flexible and the design considerations are similar to a rubberized textile belt conveyors.

Metallic strip belt conveyors are used in food, chemical industry and for conveying hot and reactive loads. Wire-mesh belts are being widely used to handle unit and lump materials through furnaces (up to 1000°C temperature), as mobile base for baking industry and also for wetting, cooling, dehydrating and similar operations.

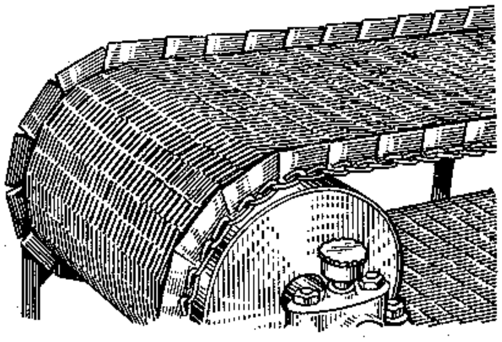

Fig. 6.1.4. Metallic belt conveyor

(*e*) **Portable Conveyor:** Short length flat conveyors carried on a wheeled structure is termed portable conveyor. These are particularly useful for loading and unloading of trucks / transport vehicles. The inclination of the conveyor can generally be adjusted to suit application.

Apart from above mentioned major types of belt conveyors, there are a few special types worth mentioning. These are:

(*f*) **Chain or Rope Driven Belt Conveyor:** In which the specially designed belt is driven by a moving chain or rope, where belt only serves as load carrier, and motion is by a chain or rope conveyor (refer section 6.2).

(*g*) **Submerged Belt Conveyor:** In which a portion of the belt moves through a metallic trough (casing) which is filled with free flowing, powdered material at the loading end. The moving belt with holes, makes the material flow to the unloading end of the trough. Fig. 6.1.5 shows a line drawing of a submerged belt conveyor.

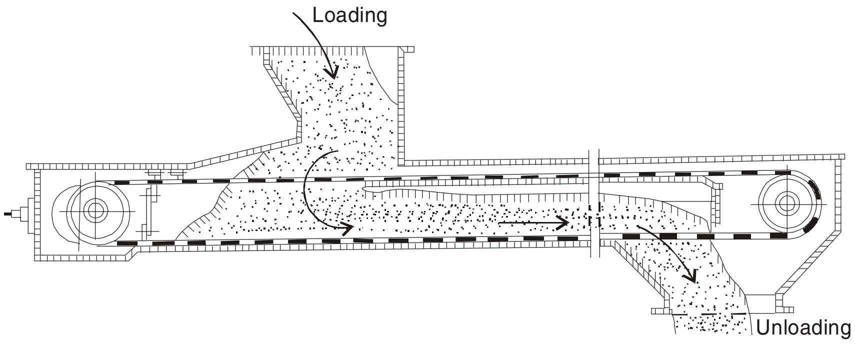

Fig. 6.1.5. A typical submerged belt conveyor

6.1.4 Parts of a Belt Conveyor

(*a*) **Conveyor Belts:** Belt, which supports and conveys the load, is the essential and most important component of any belt conveyor. Most common type of conveyor belting is rubber/plastics covered textile belting - the internal carcass of woven fabric gives the longitudinal strength of pulling the loaded belt and transverse strength for supporting the load, and the cover of rubber and/or plastics protects the carcass from damage. Specification, requirements and testing procedures of rubber/plastics, covered textile belting for conveyor (and elevator) has been given in IS 1891:1994, part I to V. Part I[1] covers the ''general purpose belting'' while the subsequent parts cover ''heat resistant belting'', ''oil resistant belting'', ''hygienic belting'' and ''fire resistant belting for surface application'' respectively.

Belt Construction: Cotton fabric ply constructed rubber covered belting is the mostly used belt for flat and troughed conveyor. The carcass consists of one or more plies of woven fabric or of solid woven fabric impregnated with a rubber or plastic mix, which after vulcanization binds the plies together. The fabric used is made of threads of cotton or polyamide or any other synthetic material or combination thereof, evenly and firmly woven. The carcass is covered by special wear and impact resisting rubber compounds / plastics. For the protection of the carcass, layer or layers of open-mesh or cord fabric, termed as ''breaker'' may be placed between the cover and the carcass, or may be embedded in the cover. Number of fabric plies varies from 3 for shorter belt widths (300mm and above) to a maximum of 12 to 14 plies for belt width of 2000mm. Number of plies can vary within a range for a specific belt width. Steel cord belting is used when good troughability, high operating tensile strength and small elongation are desired. Fig 6.1.6 shows a typical belt cross section.

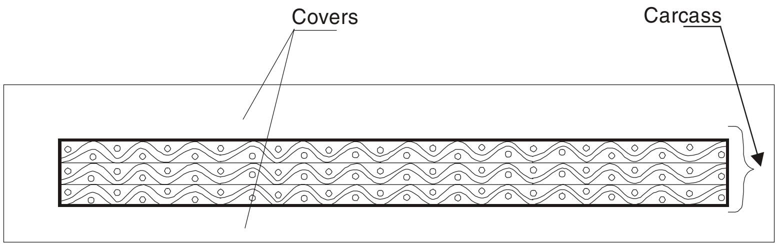

Fig. 6.1.6. Construction of a textile belt

Belt Covers: The primary purpose of the cover is to protect the belt carcass against damage. The requirements of the cover is to work satisfactorily in contact with the materials to be carried by the belt. For this purpose, sufficient thickness (not less than 1.0 mm) of top and bottom surface covers of different rubber compounds and plastics are used. Covers in the following grades are available:

(*i*) *Grade M24:* Natural rubber compound with superior resistance to cutting, gauging and abrasion.

(*ii*) *Grade N17:* Compound rubber with high abrasion resistance with inferior cutting and gauging resistance compared to M24 grade.

(*iii*) *Grade N17(Synthetic):* Composed mainly of synthetic rubber with higher abrasion resistance. Belt made of carcass with chemical or other superior bonding system should be used for this grade.

(*iv*) *Grade HR:* Suitable for handling load at high temperatures, upto 150°C for lumps or 125°C for powdered materials.

(*v*) *Grade FRAS:* Used for underground mining and processes where fire resistance and antistatic charge properties, are required.

(*vi*) *PVC Grade:* Used in fire resistance, oil resistance and hygienic belting.

Belt Designation: As per IS 1891 (Part I): 1994, belts are designated by IS No., grade of the cover, the ''type'' of belting defined by the full thickness breaking strength in KN/m and number of plies. For example, a conveyor belt with cover grade N17 and type 250 having 4 plies shall be designated as: Conveyor Belt IS 1891 (Part I) N17-250/4.

Steel cord belting is designated by prefix ''ST'' followed by the full thickness breaking strength in KN/m. Example ST-1800.

Belt Width: Unless otherwise agreed between the manufacturer and buyer, the standard widths of belting as per IS specification are:

300, 400, 500, 600, 650, 800, 1000, 1200, 1400, 1500, 1600, 1800 and 2000 mm with a tolerance of ±5 mm upto 500mm width and ±1% of belt width for widths higher than 500 mm.

Belt Splicing: Two ends of a belt may be joined either by metallic belt fastners or by vulcanization. Metal fastner joining is easier and acceptable for flat belt conveyors. Vulcanized belt splicing is a superior technique suitable for troughed belt conveyors. The later is a stepped, lapped splice in which several plies of two ends of the belt are vulcanized together to make a joint of strength almost equal to the solid belt. Skilled operator and vulcanizing equipment are necessary for such splicing at coveyor site.

(*b*) **Idlers:** The rollers used at certain spacing for supporting the active as well as return side of the belt are called idlers. Accurately made, rigidly installed and well maintained idlers are vital for smooth and efficient running of a belt conveyor.

There are two types of idlers used in belt conveyors:

(*i*) straight carrying and return idlers, which are used for supporting active side of the belt for a flat belt conveyor and also for supporting the return belt in flat orientation in both flat or troughed belt conveyor.

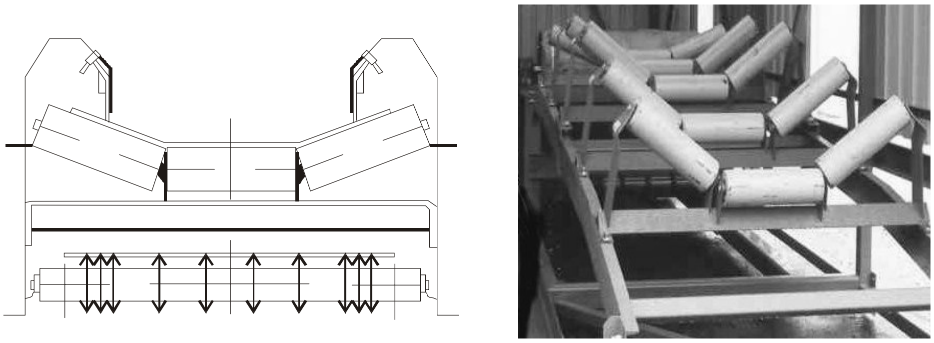

Fig. 6.1.7. Three roll idler : Sketch shows three roll carrying idler with straight return idler in same frame, and photograph shows set of assembled idlers

(*ii*) troughing idler set consisting of 2, 3 or 5 rollers arranged in the form of trough to support the belt in a troughed belt conveyor. Fig. 6.1.7 shows sketch and photograph of a 3-roll idler.

Idler construction: Idlers are generally made from steel tubes conforming to IS 9295:1983, uniformly machined all over at the outer diameter and at the two ends of the inner diameter. The tubes are mounted on antifriction bearings over a fixed steel spindle. The ends of the spindles are flat machined to standard dimensions for quick fixing in slots of idler structure. The idlers may be made of heavy steel tubes for severe service condition (like in material loading section) or cast iron in corrosive application (handling coke etc.). Fig. 6.1.8 shows different designs of roller mountings on antifriction bearings.

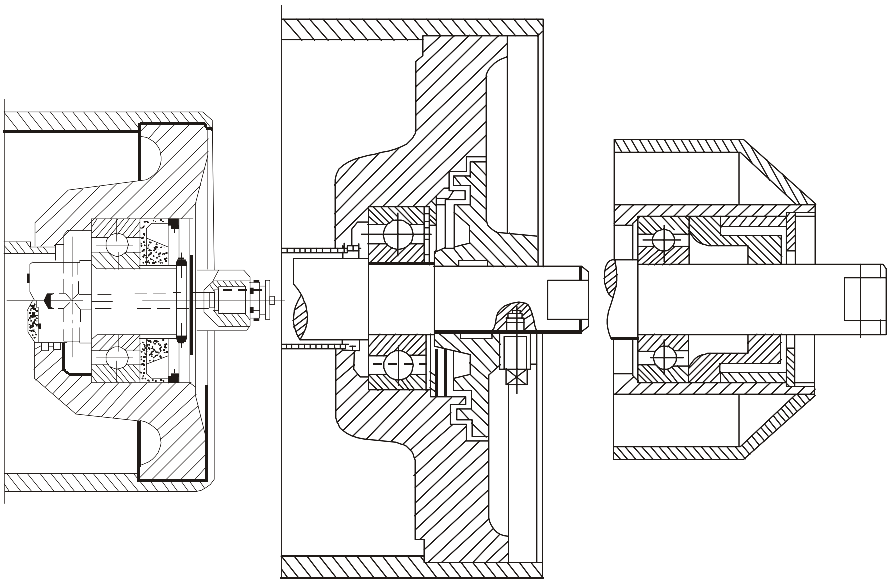

Fig. 6.1.8. Different mountings for idler roller.

Idler dimensions: Diameter, length and troughing angle have been standardized by BIS in IS 8598 :1987[2]. The carrying and return idler diameters in mm are : 63.5, 76.1, 88.9, 101.6, 108, 114.3, 127, 133, 139.7, 152.4, 159, 168.3 and 193.7. The maximum diameter of 219.1mm is used for carrying idler only. These sizes correspond to the available tube sizes. Selection of roller diameter depends on factors like bulk weight of load in kg per cubic meter, particle size and belt speed. Higher are these factors, higher is the roller size to be selected. Length of the idlers vary from 100 mm up to 2200 mm. The smaller lengths are generally made in smaller diameters while longer lengths are made in larger diameters. Troughed idler sets are made with troughing angle (the angle made by the inclined roller with horizontal) of 15°, 20°, 25°, 30°, 35°, 40° and 50°. Troughing angle of 15° is applicable only to two roll troughed idlers. The value of troughing angle of troughed return idlers are selected from 0°, (*i.e.*, straight idler), 10° and 15° for all widths of belt.

The length of the straight or troughed idler set is based on the selected width of belt, and desirable edge clearance between belt and roller edges. Table 6.1.1 shows the recommended edge clearances.

Table 6.1.1. Edge Clearance

Belt Width	Edge Clearance		
B	Flat idler	2-roll idler	3-roll idler
400	50	40	35
500	50	40	40
650	50	50	50
800	75	75	70
1000	75	75	70
1200 to 2000	100	100	100

Idler spacing: Spacing of idlers in the loaded run is a function of bulk weight of materials and width of belt. Selection of idler spacing has been further discussed in section 6.1.5(e).

(*c*) **Conveyor Pulleys:** At each of the two ends of a belt conveyor, one large diameter pulley is installed against which the belt turns and changes direction. These pulleys are called terminal or bend pulley. Drive is imparted to the belt through friction by one of the terminal pulleys called drive pulley. As the conveyor belt passes around these bend pulleys, the plies of the belt are elongated in proportion to the distance of the ply form center of the pulley. The differential elongation of one ply over the other is taken up by the rubberized bonding between two plies. Larger the pulley, less is differential elongation between the plies hence less tendency to ply separation. This is the reason the bend pulleys are made large.

The conveyor pulleys are either fabricated from rolled steel plates or of cast iron construction. The central steel shaft is keyed into the pulley drum and then the finished dimensions are machined. The pulleys are generally given a crowning at the face for keeping the belt at the centre of the pulley. The face length is generally 100 mm to 200 mm more than the belt width.

The surface of the pulley may be left bare smooth, or may be covered up to a thickness of 6 to 12 mm by rubber, polyurethane or ceramic layer with herringbone patterned grooves to increase the friction between the pulley and belt.

The pulleys are mounted on heavy duty antifriction bearings in suitable bearing housings.

(*d*) **Drives for Belt Conveyors:** The belt conveyors are generally driven at the head end pulley, where material is discharged. The drive pulley is connected to the drive motor through suitable speed reduction gear box and flexible shaft couplings. Drive of an inclined conveyor necessarily includes a braking device which prevents downward movement of the loaded belt in case of power failure of the motor.

(*e*) **Take-ups** or **Belt Tensioning Devices:** Endless conveyor belt after being threaded through the entire length of the conveyor need to be tightened so that sufficient frictional force is developed between the drive pulley and the belt, to make the belt move. Belts working under tension invariably gets elongated with time, which needs to be taken-up to maintain the desired tension in the belt. A belt conveyor generally have a screw-type (mechanical) or a gravity-type counterweighted take-up unit, also termed as belt tensioning device.

In the screw-type take-up, the bearing blocks for the tail end pulley are located in guide ways, so that these may be moved by rotating two screws as and when belt tension needs to be increased.

In gravity take up, the tail end pulley is mounted on a movable carriage which is pulled backwards along the length of the conveyor by a vertically hanging counterweight connected through a steel rope and deflecting pulleys. In an alternate design, the return side of the belt passes by the bottom of a counter-loaded deflictor roll which is free to move down to keep the belt taught. Fig. 6.1.9 illustrates the two gravity take-up arrangements.

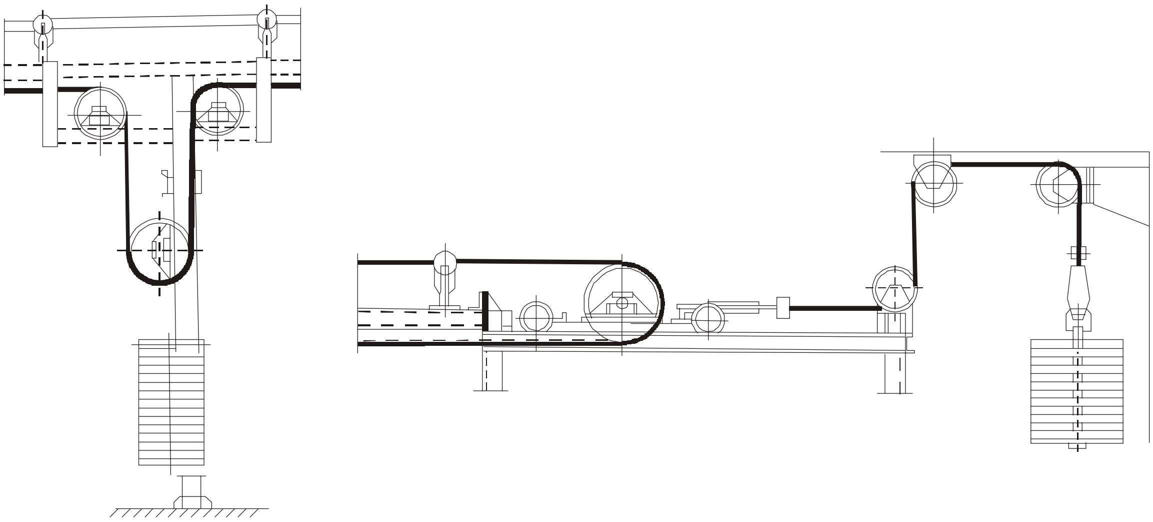

Fig. 6.1.9. Typical gravity take-up arrangements.

(*f*) **Loading and unloading devices:** Free flowing material may be directly delivered from a hopper, bin or storage pile through a chute, the delivery rate being controlled by a regulating gate at the hopper / bin output. For non free flowing materials a suitable feeder unit with a chute is used for loading the material centrally onto the belt as evenly and gently as possible. Side boards or skirt plates, extending a considerable length (2 to 3 m), is generally attached to the conveyor structure to be placed centrally to the belt, covering 2/3rd to 3/4th width of the belt, and maintaining a small clearance with the moving belt.

For unloading of materials at the end of the head pulley, no device is required excepting proper chutes to guide the discharged materials. For discharging at any point along the length of the conveyor, a plough or a belt tripper is used. A plough consists of a rubber tipped blade extending across the belt width at an angle of 60°. The plough may be one-side discharge or a V-shaped blade for two-side discharge. The belt carrying material must be made flat passing over a slider plate at the plough to allow close contact between the belt and rubber tipped blade. Plough is pivoted so that its position can be adjusted above the belt to allow control of material being discharged.

A belt tripper is an unloading device which consists of two pulleys, of comparable size of the head pulley, supported in a fixed or movable frame. One pulley serves to elevate the belt a sufficient height from carrying rollers to permit a discharge chute to be set under the pulley. The chute receives the entire amount of material flowing over the pulley and discharge it on one or both sides of the conveyor. The belt passes around the second pulley and beneath the chute, to resume its position on carrying rollers.

(*g*) **Belt Cleaners:** For cleaning the outer surface of the belt a wiper or scraper blade is used for dry particles adhering to the belt. A rotary brush type cleaner is used for wet and sticky materials. To clean the inner surface of belt, if warranted, a scraper is placed near the end of return run before the tail end pulley.

(*h*) **Training idlers:** For various reasons like eccentric loading, sticking of material to belt or idlers etc., particularly for a long-centre conveyor, the belt may tend to move out of centre line. To prevent this tendency, belt training idlers are used which automatically maintain belt alignment.

The belt training idler consists of an ordinary troughed idler which is mounted on its base by pivot shaft about which it can swivel within a limited angle. Two short vertical rollers, mounted on bearings are fixed at the two ends of the idler, such that they are perpendicular to the belt edges. The vertical rollers are placed slightly ahead of the idler centre line.

When the belt shifts off centre, it makes contact with one of the vertical rollers which makes the entire idlers frame to swivel through an angle. This skewed position of the idler creates a force which tends to bring the belt back to its central position.

In a long conveyor, such trainer idlers may be spaced at about 30 meters. Fig. 6.1.10 shows such a troughed belt training idler.

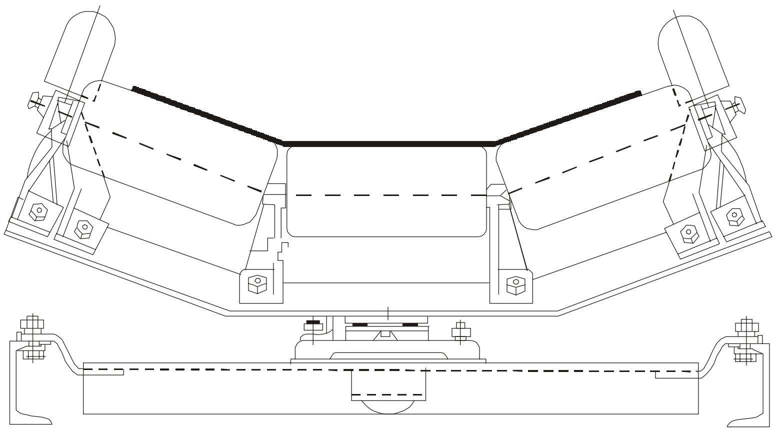

Fig. 6.1.10. Troughed belt training idler

To align belt travel, at times, troughed idlers having its side idlers tilted to a small angle not more than 3°, are used. However, this tilted rollers cause the belt to wear rapidly, hence should be used with caution.

(*i*) **Conveyor structure:** The structure supporting the pulleys and idlers consists of suitable sized channel stringers, with supporting legs to the main structure or floor. For long conveyors, 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 $B \leq 2$ 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 :

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

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

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

where,

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

V = velocity of belt in m/sec.

B = Belt width in metres.

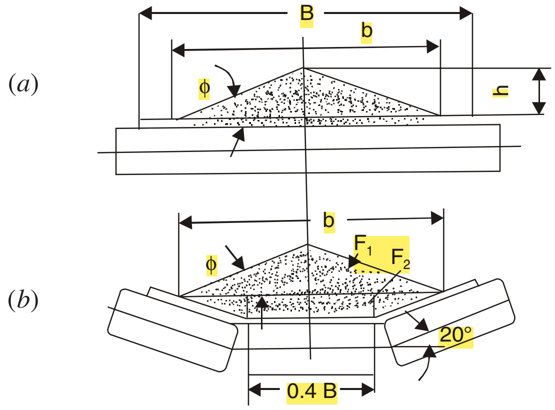

Fig. 6.1.12. Bulk load on flat and troughed belt conveyor

(*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

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

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.

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

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

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

(*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,

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

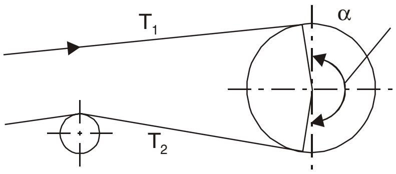

Fig. 6.1.13. Tensile forces on belt

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.

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

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.

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

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:

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

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

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'.

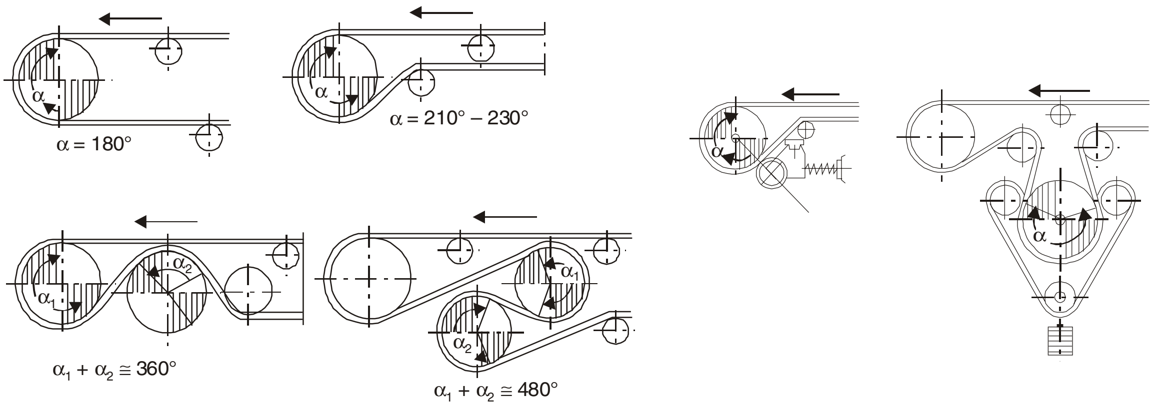

Fig. 6.1.14. Different belt drive arrangements

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 $T_{1max} = T_e \xi \left(\frac{e^{\mu a}}{e^{\mu a} - 1} \right)$. 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:

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

$P_A = \frac{T_e V}{1000} + \frac{(R_{wd} + R_{bd})V}{1000}$ 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, $P_M = \frac{P_A}{\eta}$.

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.