# BELT CONVEYORS



## 1. Definition / Description and General Characteristics

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.

Belt conveyors operate in one vertical plane, horizontally or with an inclination (up or down) depending on the frictional property of the load conveyed. For changing direction of the materials being conveyed, in the horizontal plane, more than one belt conveyors are needed. Conveying capacity of a conveyor can be controlled by changing belt speed. Belt conveyors are generally employed for continuous flow of materials. Metal/special belts can carry hot, abrasive or reactive materials.

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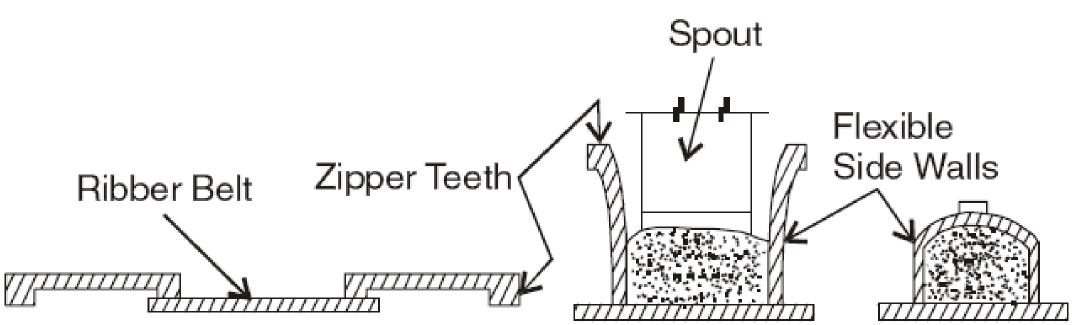
## 2. Types of Belt Conveyors

**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.1. A flat belt conveyor with drive control

**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: transportation of the output of mines to the processing plants, materials from shipping ports to the storage/transport loading sites, materials from outdoor storage yards to inside plants, movement of materials between plants etc.

**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: it can handle fragile materials safely and without breaking by reducing inter particle collision, it can handle fine bulk materials without being swept by air (however, it is not really air tight at loading and unloading points), ability to handle corrosive and reactive materials without contamination and 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. 2, a type called Zipper Conveyor is shown. Fig. 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.



Stages of belt being loaded and closed

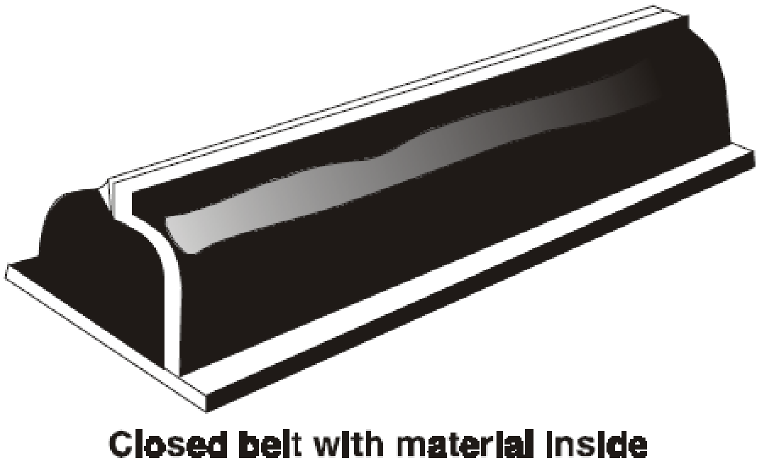



Fig. 2. Endless zipper belt

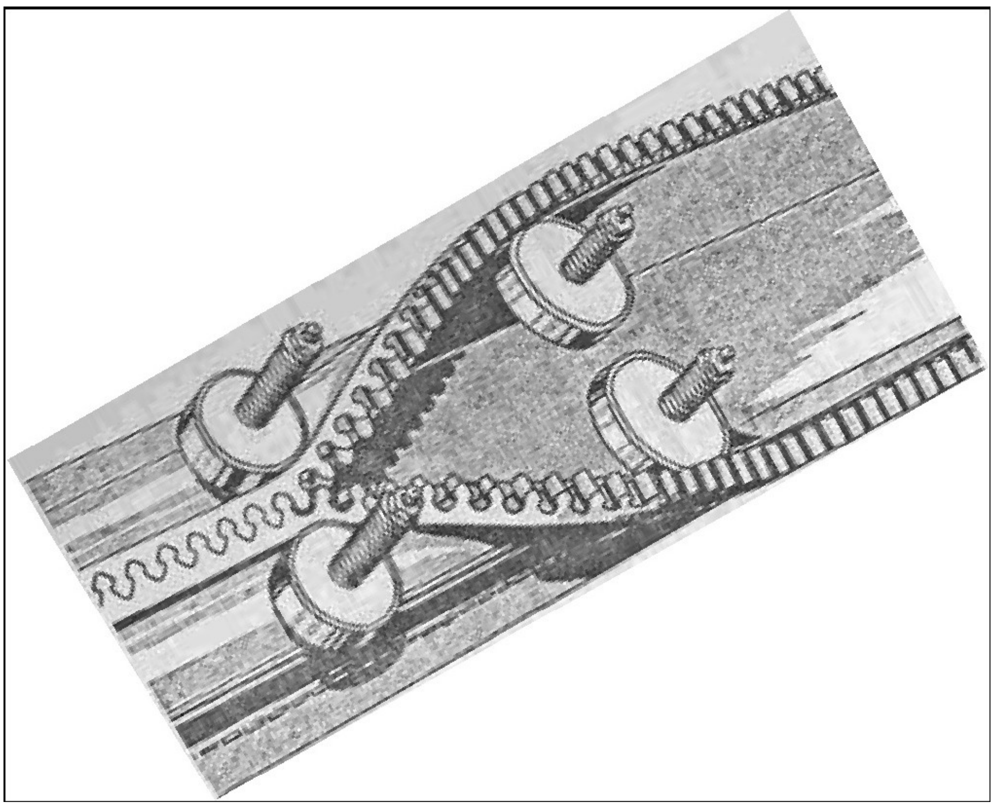


Fig. 3. Spreading, filling and locking of a closed conveyor

**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.

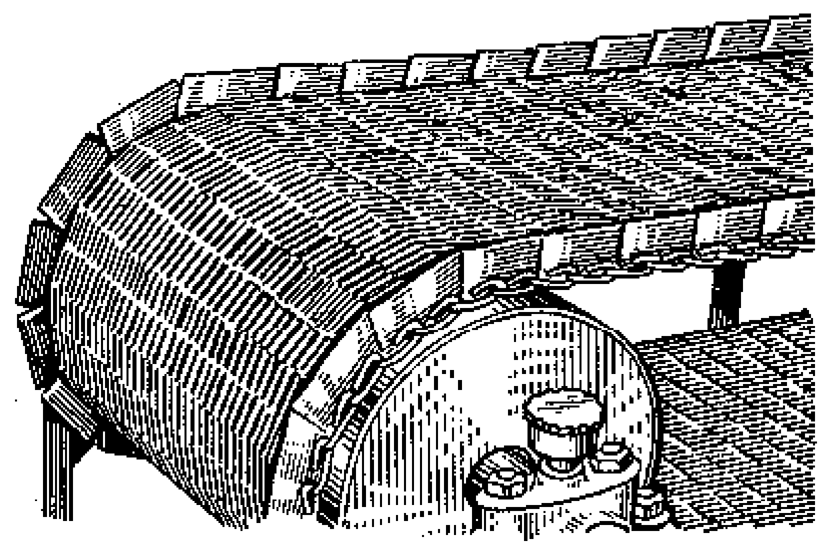


Fig. 4. Metallic belt conveyor

**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:

**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.

**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. 5 shows a line drawing of a submerged belt conveyor.

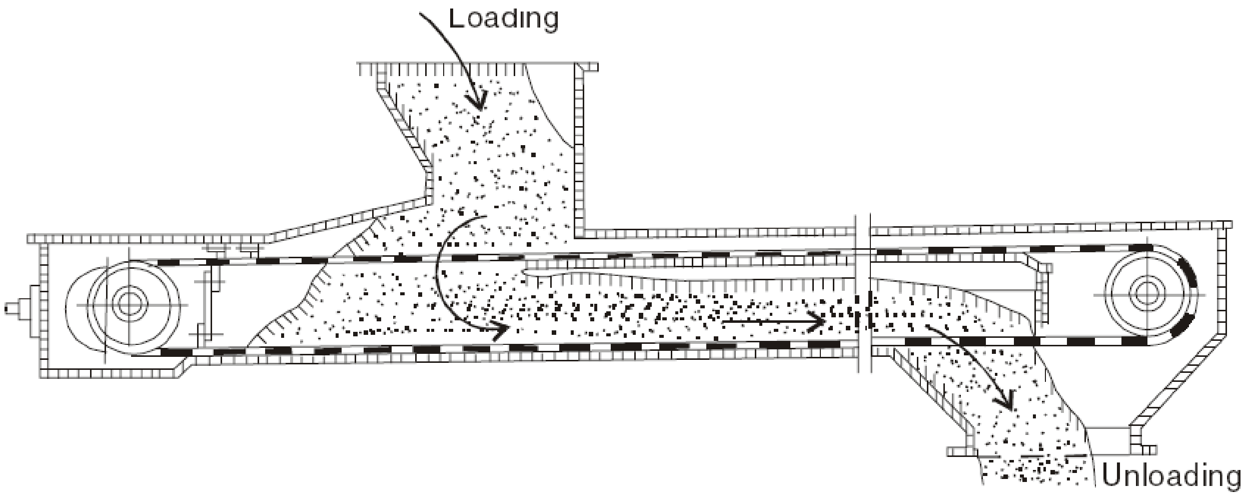



Fig. 5. A typical submerged belt conveyor

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## 3. Parts of a Belt Conveyor

**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 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 shows a typical belt cross section.

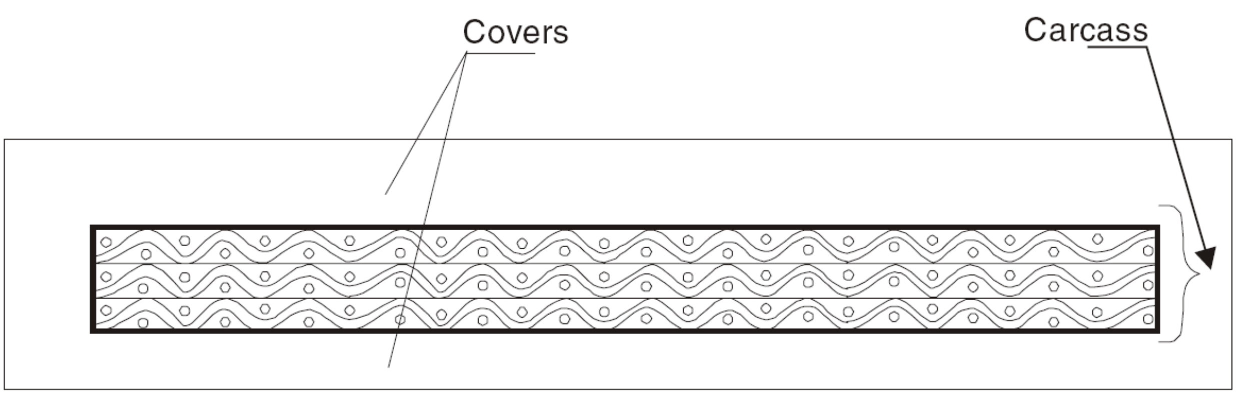



Fig. 6. Construction of a textile belt

**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.

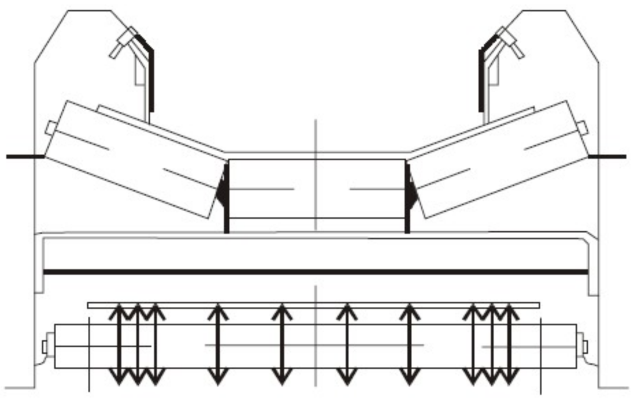
**Belt Designation:** As per IS 1891 (Part I): 1994, belts are designated by IS No., grade of the cover, the ''type'' of belting defined by the full thickness breaking strength in KN/m and number of plies. For example, a conveyor belt with cover grade N17 and type 250 having 4 plies shall be designated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

**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: 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;  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. 7 shows sketch and photograph of a 3-roll idler.



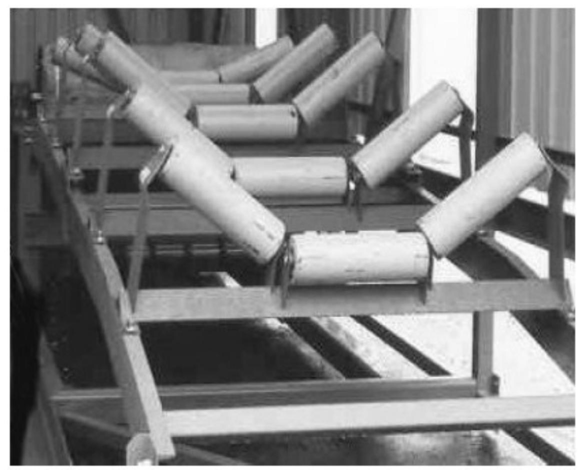


Fig. 7. Three roll idler : Sketch shows three roll carrying idler with straight return idler in same frame, and photograph shows set of assembled idlers

**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. 8 shows different designs of roller mountings on antifriction bearings.

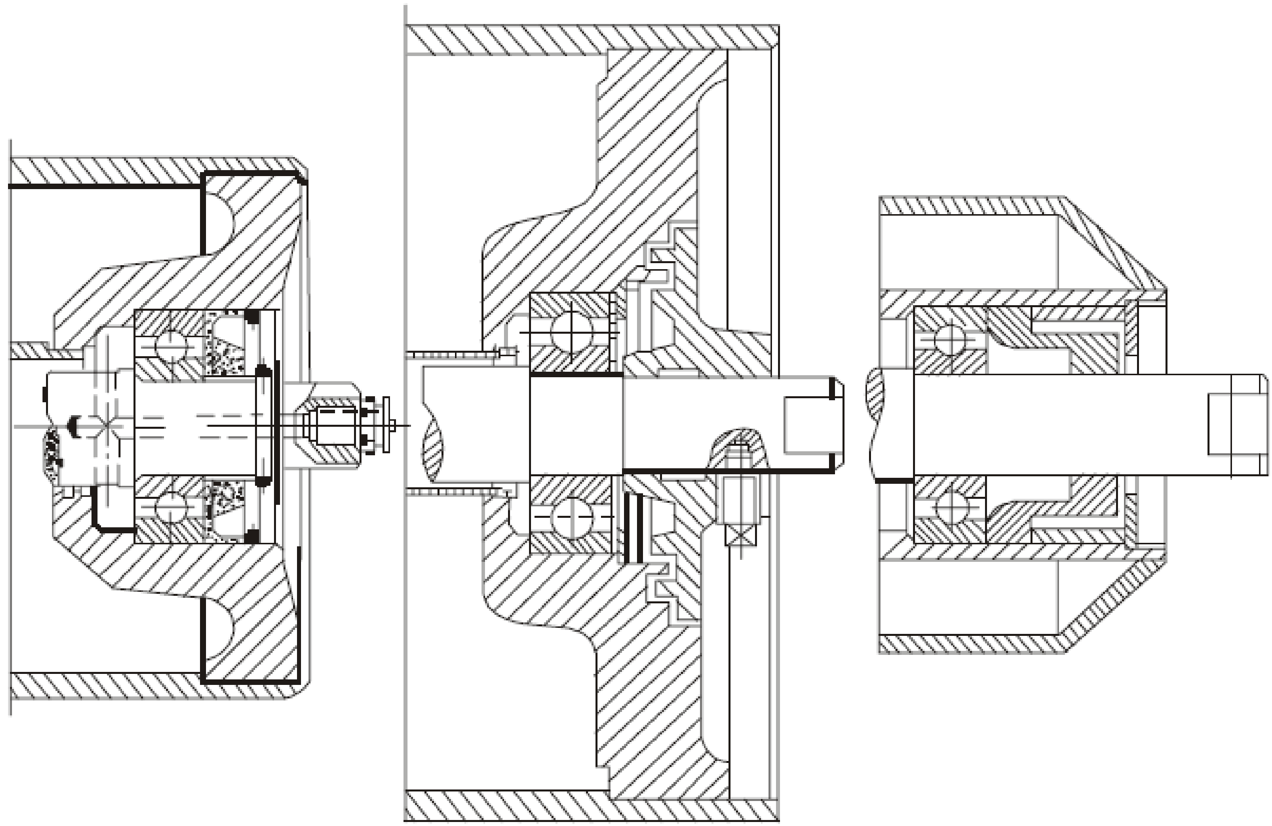


Fig. 8. Different mountings for idler roller

**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 1 shows the recommended edge clearances.

Table 1. Edge Clearance

| Belt Width B | Edge Clearance | | |
|---|---|---|---|
| | 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.

**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.

**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.

**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. 9 illustrates the two gravity take-up arrangements.

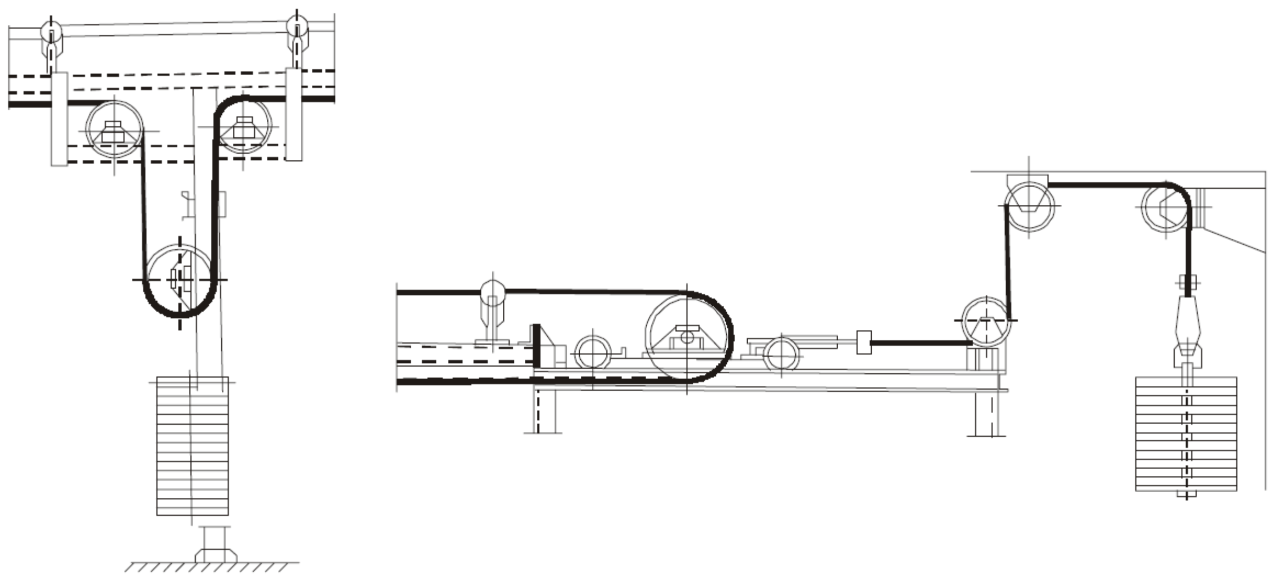


Fig. 9. Typical gravity take-up arrangements

**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 oneside 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.

**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.

**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. 10 shows such a troughed belt training idler.

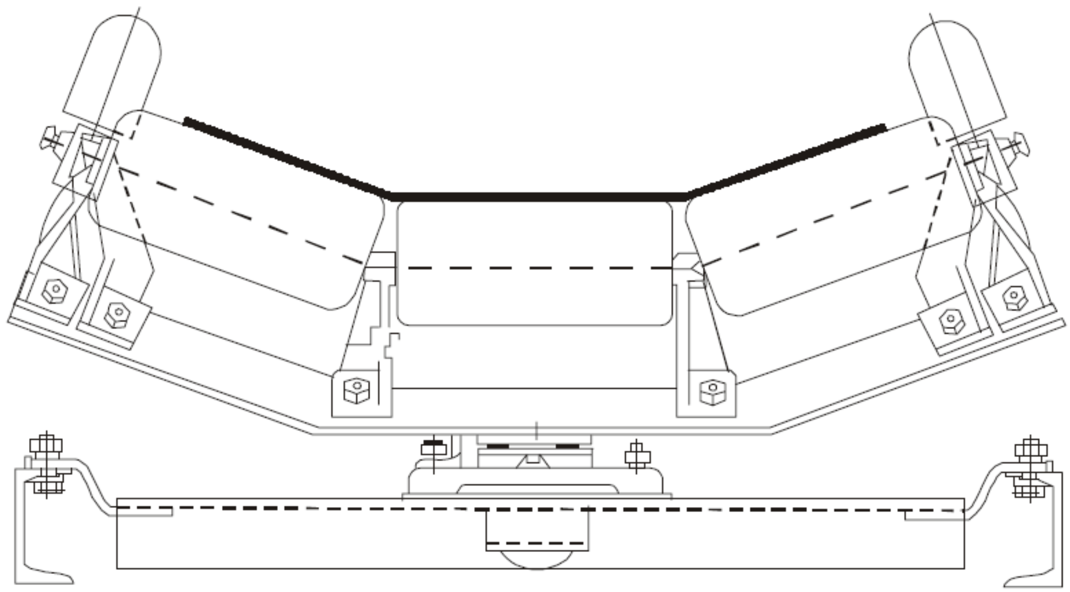


Fig. 10. Troughed belt training idler

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.

**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.

**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.

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## 4. Aspects of Belt Conveyor Design

The major points in selection and design of a belt conveyor are: Checking/determining capacity of a conveyor; Calculating maximum belt tension required to convey the load and selection of belt; Selection of driving pulley; Determining motor power; 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.

**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:** On a flat belt, free flowing materials will assume the shape of an isosceles triangle (Fig. 12 [*a*]). The angle of dynamic repose ''φ1'' 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 ≤ 2 m. Therefore, the assumption $b$ = 0.8B is more conservative for B > 500 mm. Referring to

Fig. 12(*a*), the cross sectional area of the load on a flat belt is

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

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

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

where,

$\gamma$ = bulk density of material in tons /m$^3$, and

V = velocity of belt in m/sec.

B = Belt width in metres.

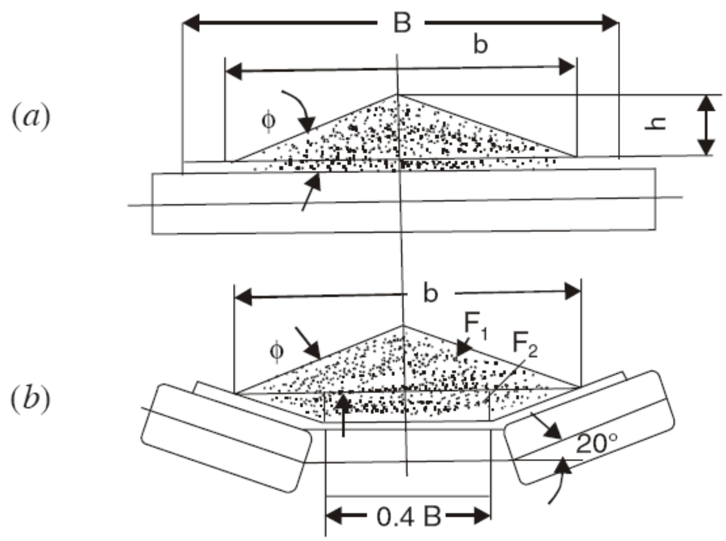


Fig. 12. Bulk load on flat and troughed belt conveyor

**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 4 shows the recommended maximum belt speeds. Higher belt speeds may be considered under special design conditions only.

## Table 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 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 4. Maximum Recommended Belt Speeds (m/s)

| Belt Width, mm / Speed Factor | 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 |

**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

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

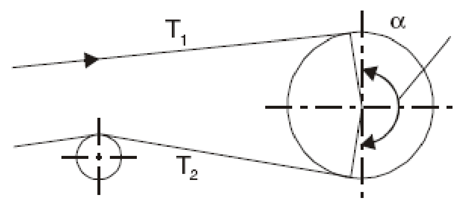

**Fig. 6.1.13.** Tensile forces on belt

where, $T_1$ = Belt tension at tighter side

$T_2$ = Belt tension at slack side

$\alpha$ = Wrap angle in radian

$\mu$ = 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.

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