# Joining Conveyor Belting

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## 1) Introduction

A conveyor belt is not a conveyor belt until it is joined. Ideally the join should not impose limitations on the conveyor design. However, in practice this is not the case and the ultimate minimum safety factor that can be applied must allow a significant loss of strength in the join. This paper discusses the loss of strength in the three main types of belting joined by different means. It also highlights the reasons why the belt join often does not perform to its full potential.

## 2) Safety Factors

The safety factor that has traditionally been used in belt conveyor design has been the ratio between the whole belt strength and the calculated steady state belt tension. Typical values of 10:1 for textile reinforced belting and 6.67:1 for steel cord reinforced belting have been used since about 1970. Dynamic belt forces have been studied since 1955 and since about 1995 reasonably accurate models have become available that allow dynamic forces to be calculated [1]. Knowledge of these forces allows the safety factor to be based on the calculated maximum dynamic load. But the safety factor is still based on the calculated steady state belt tensions.

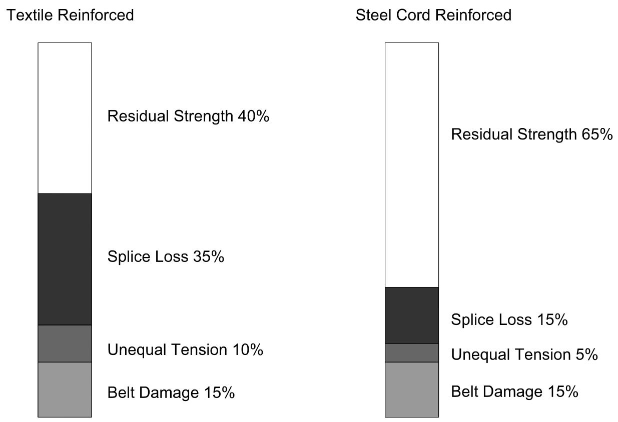


**Figure 1** Residual belt strength

During service the belt reinforcement can loose strength through fatigue, impact, cutting etc.. In a well maintained system the loss of strength from these factors is typically 15% of the belt strength. By virtue of the fact that the belt runs in a troughed cross section unequal forces are imposed on the tension carrying members at transitions and in vertical curves. Normal design limits these unequal forces to 5% of the belt strength. In the case of textile reinforced conveyor belts, unequal forces (up to a maximum variance of 5% of belt strength) are applied to the inner and outer tension carrying members when bent around a pulley. The maximum splice strength that can be achieved in a textile reinforced belt is between 65 and 80% of the belt strength. In a steel cord reinforced belt the splice strength has a maximum of 85 to 100% of the belt strength. A typical chart of belt strength losses is shown in figure 1.
Suppose that the maximum belt force is 150% of the calculated steady state force in the case of textile reinforced belting and 140% of calculated steady state force in the case of steel cord reinforced belting. In the case of textile reinforced belting this amounts to 15% of the breaking strength and in the case of steel cord reinforced belting it is 21% of the breaking strength. If these forces are applied the safety factors are 2.67:1 for textile reinforced belting and 3.1:1 for steel cord reinforced belting respectively, calculated against the residual strength.

## 3) Methods of Joining Belts

Three basic belt constructions dominate belt conveyor systems for bulk materials handling.

a) Multiply textile reinforced belting
b) Solid woven textile reinforced belting
c) Steel cord reinforced belting.

There are three systems by which belts can be joined. By means of mechanical fasteners, cold curing adhesives or a hot vulcanisation process. Table 1 shows the strengths and the weaknesses for each of the three systems as a joining method for the three common belt constructions used in bulk materials handling.

| Belt Type | Joining method Mechanical fasteners | Cold curing adhesives | Hot vulcanisation process |
|---|---|---|---|
| Multiply textile reinforced | Effective method up to class 1600. Join strength up to 60% of the belt strength can be achieved. Some fastener systems require special tools. Downtime 1 hour. Join life 15000 cycles. | Efficient method for all strength ratings. Join strength 66% to 80% of belt strength. No special equipment is necessary. Downtime 6 to 12 hours. Join life 100000 cycles. | Efficient method for all strength ratings. Join strength 66% to 80% of belt strength. Vulcanising press is required. Properties of the join the same as the belt. Downtime 6 to 12 hours. Join life 200000 cycles. |
| Solid woven textile reinforced | Efficient method for all strength ratings. Join strength up to 75% of the belt strength can be achieved. Most fastener systems require installation machine. Downtime 1 to 2 hours. Join life 25000 cycles. | Effective skive method up to class 315. Join strength up to 50% of the belt strength can be achieved. Downtime 8 hours. Join life 30000 cycles. | Efficient method for all strength ratings. Join strength 75% of the belt strength. Vulcanising press is required. Downtime 6 to 8 hours. Join life 100000 cycles. |
| Steel cord reinforced | Effective method up to class 1600. Join strength up to 40% of the belt strength can be achieved. Limited availability of fasteners. Downtime 4 to 6 hours. Join life 1000 cycles. | None available. | Efficient method for all strength ratings. Join strength greater than 85% of the belt strength. High pressure vulcanising press is required. Downtime 10 to 14 hours. Join life 500000 cycles. |

**Table 1** Strengths and weaknesses of the three belt joining methods

Although mechanical fasteners are available for steel cord reinforced belting, the join has a very limited life. As such this method of joining steel cord reinforced belting should not be considered as a viable option.

Special tools used to install mechanical fasteners in textile reinforced belts ensure consistent results with very limited training. The low impact on downtime and relatively low cost of the mechanical fastener system has made this the method of choice for joining solid woven textile reinforced belts.

## 4) Design of Belt Splices

a) Multiply textile reinforced belt splices
The tension is transferred from a ply in one belt length to an adjacent ply in the other belt length through an intermediate layer of rubber. The plies must overlap by a distance that is sufficient to ensure that the shear strength of the intermediate layer of rubber is higher than the breaking strength of the plies on either side. To ensure that the thickness and stiffness of the splice match the belt, the number of plies and the thickness of intermediate rubber in the splice must match the belt. Each side is stepped with the number of steps being one less than the number of plies.

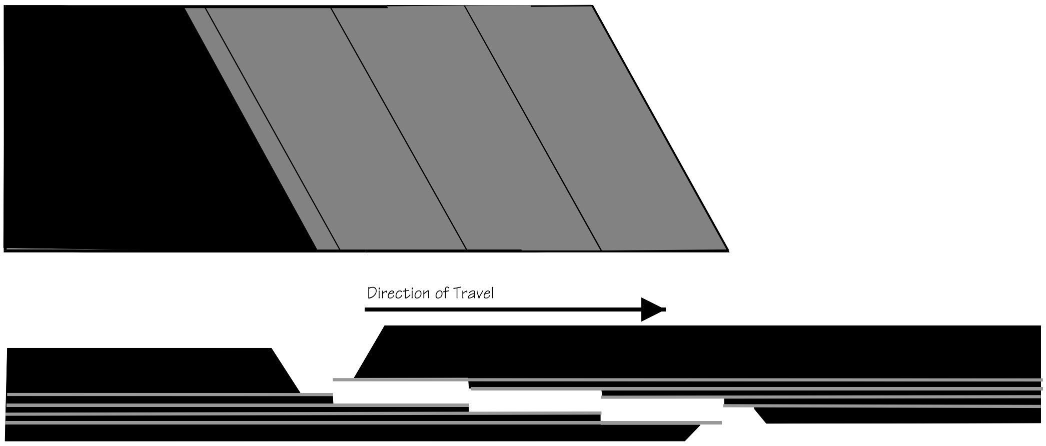


**Figure 2** Four ply textile reinforced belt splice

In the case of a two ply construction two steps are made and overlapped so that there are three plies in the splice. The intermediate rubber used in the splice must be thinner than the belt interply to ensure that the overall belt thickness remains constant through the splice.

b) Solid Woven textile reinforced belt splices
Triangular fingers are cut into the belt ends to be joined. These are brought together,

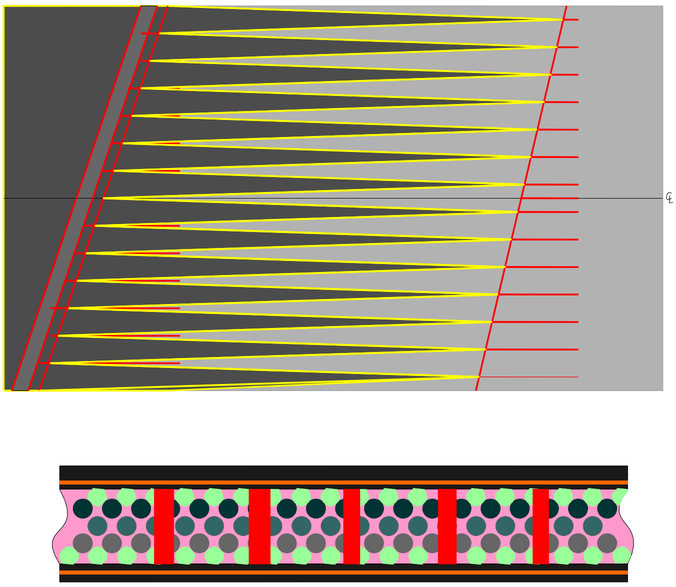

**Figure 3** Solid woven finger splice

leaving a gap between the fingers from each side. The gap is filled with paste, a reinforcing fabric placed above and below the fingers and then covered with a protective elastomeric material. The entire splice is 'cured' in a press by the application of pressure at a temperature of 165ºC.

c) Steel cord reinforced belt splices
The rubber surrounding the steel cords is removed. The cords from each belt end are then laid adjacent to one another and the intermediate gap filled with unvulcanised rubber. Unvulcanised cover rubber is placed on either side of the cord line and the entire splice is vulcanised in a field vulcanising press by the application of pressure at a temperature of 150ºC.

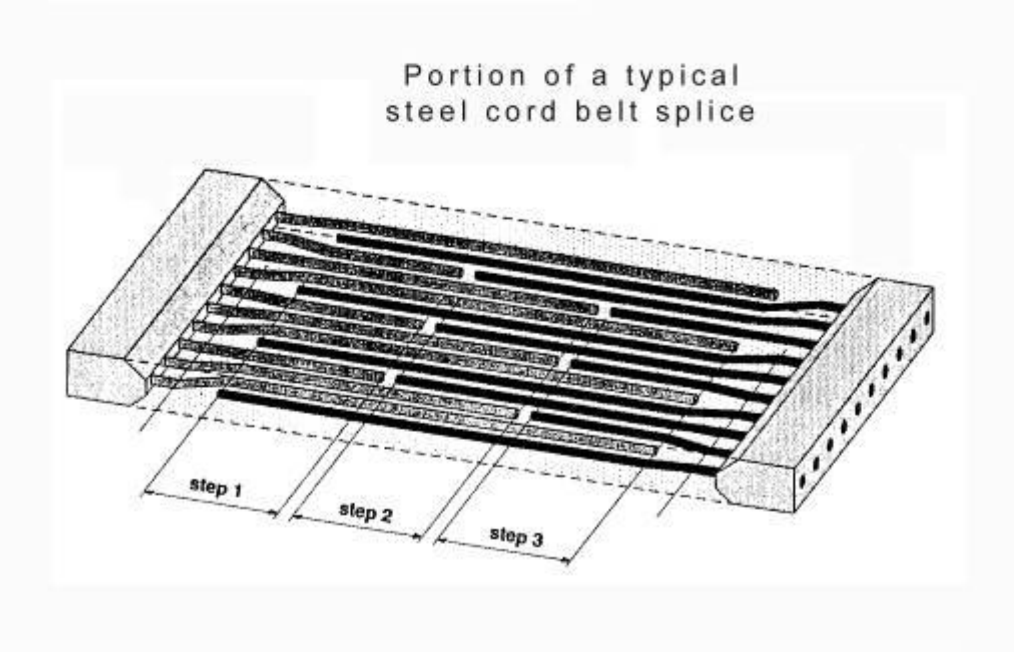


**Figure 4** A 3 step (stage) steel cord belt splice

## 5) Limitations imposed by the splice design

The design of a multiply belt splice is such that for a belt with 3 or more plies, the strength of an entire ply is lost. The ultimate splice strength is limited by this factor, the bond strength between the intermediate rubber and the belt carcass and the strength of the intermediate rubber. The strength of the intermediate rubber is a function of its thickness and the splice length. The thickness of the intermediate rubber must be limited to the same thickness as the un-spliced belt.

For finger splices the ultimate strength is determined by the strength of the material between the fingers, the bond strength of the material between the fingers to the fingers and the strength of fingers themselves. The strength of a finger is related to its length and base width. The ratio between these dimensions also determines the shear angle acting at the interface between fingers. The strength of the intermediate material and the forces that must be transferred by the material play a role in determining the finger length. Some practical limitations are imposed on the finger length and width to reduce splice preparation time.

Steel cord belt splices are very similar to finger splices. The tension in one belt end is transferred to the other belt end through the rubber between the adjacent cords. The ultimate splice strength is determined by the strength of the rubber between the cords, the bond strength of the rubber to the cords and the strength of cords themselves. The embedded length of cord and the gap between adjacent cords that is filled with rubber, to a large extent dictate the ultimate strength. Where the belt strength is very high the ratio between the cord spacing and cord diameter becomes small and it becomes more difficult to design splices with sufficient rubber between adjacent cords to ensure a high splice strength. Special splice layouts are necessary as depicted in diagram.

## 6) Measuring the splice efficiency

One of the most difficult problems in establishing the actual safety factor is in determining the strength or efficiency of the belt join. Test work that has been conducted in conjunction with the CSIR test facility shows a poor correlation between small laboratory test samples, full width samples and theoretical strength when breaking strength is measured.

In 1975 the Institut für Fördertechnik, Hannover developed a test rig for dynamic splice strength testing [2]. This test rig subjects a nominal 12 metre long spliced endless belt to a cyclic load. The applied load represents a typical load cycle in which the belt tension increases from a minimum T2 value just behind the drive pulley to a maximum T1 at the drive pulley. A number of similar samples with various Tmax levels are run on the test rig at a constant speed of 6 m/s. The highest value T1 applied to the test sample which allows the spliced belt to achieve 180000 revolutions is taken to be the ultimate fatigue strength of the splice. The fatigue strength efficiency is then the ratio between T1 and the nominal whole belt strength expressed as a percentage. Typically the fatigue strength efficiency measured in this way ranges from 35% to about 65%. The test rig has been used effectively to improve the fatigue efficiency of high strength splices but has limited practical value in determining the splice life under normal operating conditions.

In 1984 the CSIR at Cottoesloe commissioned special clamps for the 10000 kN tensile testing facility that allowed belt samples of up to 1200 mm width to be subjected to tensile forces of up to 10000 kN. This allowed full width break strength to be measured. The additional clamps for the test rig were made to specifically test full width samples of solid woven belting. This was to establish the degree of accuracy of laboratory fastener pull out tests and to compare finger splice strength to fastener strength. Using this facility there have been attempts to measure the ultimate efficiency of splices in steel cord reinforced belting.

## 7) Computer simulation

A lot of work has been done on building computer models of steel cord reinforced belt splices. Using these models and information obtained from small test samples the stress levels in a particular splice pattern can be determined. These modelling techniques ensure that new splice patterns are as efficient as possible. Credibility of these models is lacking and no organisations are prepared to accept results from a computer simulation without a physical test of a splice.

## 8) Why belt joins fail

Given that no portion of any belt join will see a tension in excess of 30% of the breaking strength of the belt, why do they fail so frequently? There are a number of factors. The first being the amount of impact and abuse to which the belt is subjected. Secondly, the quality of the workmanship in making the splice leads to very low fatigue strength. Thirdly, the conditions under which the joins must be made are not always conducive to a good quality join. Further more the belting is often so badly damaged and worn that making an efficient join is impossible.

Poor workmanship can be the result of time pressures, inadequate lighting, limited access and other environmental factors and therefore is directly linked to conditions under which the belt must be joined. However, poor workmanship can also result from the standard of training or the level of skill of the labour.

The installation of mechanical fasteners has been automated by using special tools. With relatively little training most artisans can acquire the necessary skill to perform this task well. Provided the condition of the belting is good the quality of the join is normally very consistent and hence the life of the mechanical fastener join is likely to be consistent. Fatigue and wear of the mechanical fastener join will eventually lead to its failure. The rate of failure is normally very predictable and it is therefore relatively easy to adopt a process of planned join replacement to eliminate failures.

This is not the case for belt splices. Every splice is unique and is, in the main, hand crafted. The skills required to make a good splice are acquired over a relatively long period of time and are not a guaranteed outcome of any training programme.

The team tasked with making the join must make-do with an allocated site and work under severe time restraints even when the work has been planned. These are not the conditions under which masterpieces are created.

## 9) Splice analysis

It is impossible to determine the life for any given splice. It is mainly dependent on the condition of the two belt ends being joined and the quality of the work. There are some indicators of the quality of the finished splice such as the appearance, dimensional accuracy and belt tracking. In the case of hot vulcanised splices the quality of the polymer can be determined by measuring the hardness. However, all of these measures do not indicate whether the internal polymer is well bonded or has the required strength to ensure a long splice life.

The splice should be carefully inspected at regular intervals. Any opening at edges or ends should be cause for replacement. Cracks coinciding with the position of step ends or along the finger gaps are early signs of splice fatigue. Permanent marks should be made at the four corners of the splice and dimensions between these corners measured at regular intervals. Any increase in the sum of the diagonal and longitudinal dimensions between the corners should also be reason to replace the splice. Steel cord splices can be scanned by electromagnetic flux leakage equipment or x-ray equipment. Comparison of the scan images of each splice should be made to assist in determining the splice integrity.

## 10) Conclusions

Sophisticated tools are available for the detailed study of various splice designs and evaluation of splice materials. However, the reasons for the majority of splice failures have nothing to do with the design of the splice or inherent properties of the splice materials. More often than not splices fail because of poor workmanship, taking short cuts to save time, difficult environment in which to work and poor condition of belting.

For these reasons more effort should be assigned to the following:

a) A dedicated splice station on all conveyors. In the splice station there should be adequate lighting and ventilation. The area should be flat and have easy and safe access from all directions. Permanent and safe belt clamping positions should be located at each end of the splice station.

b) Professional skills training for belt splicing. After completion of training the pupil should be evaluated and graded according to their ability to perform the tasks accurately and efficiently.

c) Development of more automated splice procedures which eliminate the need for skilled craftsmen.

d) Clearly defined splicing procedures and auditing of splice work to ensure that the splice procedure is followed.

References

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