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Cost Reduction in Belt Conveying – Cost-efficient and Application-oriented Design of Steel Cord Conveyor Belts for the Mining Industry

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Conveyor belts in the mining industry are facing ever higher demands as regards conveying capacity, conveyor length, service life and energy efficiency. In addition to designs acc. to various general standards manufacturers further develop their products for better economy.

Seel cord belts are in widespread use in the mining industry. They are used primarily for long-distance conveyors, heavy mining machinery (rotary disc excavators, overburden conveyor gantries, tractor shovels, bucket-chain excavators, stackers, spreaders, loaders, etc.), short- and middle-distance belt conveyors in surface mining and in general wherever high conveying capacities and small takeups are required. In this connection, two important properties of a steel cord conveyor belt compared to a fabric ply conveyor belt are critical: high nominal breaking strengths with low reference elongations. Today, conveyor belt designers have at their disposal a broad range of design standards and modern materials, meaning that belt manufacturers are able to design conveyor belts in a cost-efficient and application-oriented way – corresponding exactly to the customer’s needs. This article provides an overview of the opportunities relating to how belt manufacturers and end customers can jointly achieve these goals.

Furthermore, the new product Stahlcord Barrier from the Contitech Conveyor Belt Group is presented here as an example for this approach.

Various Standards influence the Design of Steel Cord Conveyor Belts

The selection of the cord breaking strength or the cord diameter and the cord pitch of a steel cord conveyor belt has a strong influence not just on its manufacturing costs and the degree of difficulty of the splicing, but also on elements of the belt conveyor system. For example, in the selection of a pulley diameter conforming to DIN 22101 [1], a cord diameter is multiplied by a numerical factor. This value is used in combination with the pulley load factor in the determination of the system’s pulley diameter. Fig. 1 shows a typical steel cord conveyor belt along with its components and important parameters.

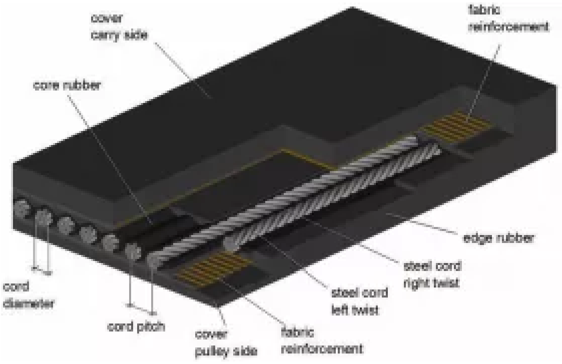

Fig. 1: Steel cord conveyor belt with two fabric reinforcements. (Picture: © Contitech)

Depending on the application, the parameters and components of a conveyor belt are determined by the belt manufacturer in consultation with the customer. In terms of design, it is often not just internationally known standards that are taken into account, but also the internal company standards of the customer. In addition to many national standards (AS, CEMA, GOST, DIN, NF, etc.), the following standards are most frequently used in the design of a steel cord conveyor belt and its splice.

- German Industrial Standard DIN 22131 parts 1 to 4 [2]
- International Standard EN ISO 15236 parts 1 to 4 [3]
- Australian Standard AS1333 [4]

In spite of the fact that DIN 22131 has been withdrawn and replaced by EN ISO 15236 (DIN EN ISO 15236), DIN 22131 is still used worldwide because of the many years of good experience of OEMs and end customers.

In all three standards, the recommendations for selecting the parameters for a steel cord conveyor belt are summarized in the form of a table. This table with preferred belt types contains information about minimum breaking strength of a belt (N/mm), maximum cord diameter, minimum breaking strength of the cord, cord pitch, minimum thickness of the cover plates, and the number of cords as a function of the belt width. Therefore, the design of belt types of St500 to St5400 or St6300 that are used most often is predetermined. The recommended belt designs always include strength reserves that are achieved by higher cord breaking strength and number of cords. Depending on the application, the strength reserves should be critically analyzed because they can result in increased costs of a steel cord conveyor belt and the system components (e.g. pulley).

The German Industrial Standard DIN 22131 part 1 specifies that the breaking strength of a steel cord vulcanized into the conveyor belt must be at least as great as the product of minimum breaking strength of the conveyor belt and the cord pitch according to the table with recommended belt designs, with an allowance of approximately 10%. The Australian Standard AS1333 determines for each belt strength class and belt width the number of cords, cord pitch, and minimum cord breaking strength. Therefore, the strength reserves are pre-programmed in both standards.

While German or Australian standards allow low “freedom” in the design of a steel cord conveyor belt, the International Standard EN ISO 15236 (and DIN EN ISO 15236, resp.) is more flexible in this regard. In addition to the recommended belt designs conforming to EN ISO 15236-A1 and -A2, the following applies in the selection of the number of cords:

“Based on the minimum breaking strength of the cord F_{bs} in kN, the minimum breaking strength of the belt (k_N) in N/mm, and the width of the belt B in mm, the minimum number of cords (n_{min}) is calculated according to the following equation:“

$$n_{\min} = \frac{k_N \cdot B}{F_{bs} \cdot 1000}$$

“The actual number of cords, *n*, must be greater than or equal to $n_{\min}$. The number of cords in the tables should be regarded as a recommendation only. It results from the equation Eq. (1) and from the requirement that the edge width cannot be greater than 40 mm and cannot be less than 15 mm”, i.e.:

$$15\text{ mm} \leq b_k \leq 40\text{ mm}$$

“A higher number of cords as well as a lower number can be selected if the conditions are met with regard to the minimum breaking strength as defined in EN ISO 15236-1 and EN ISO 15236-4.”

$$k_N = \frac{F_{bs} \cdot n \cdot 1000}{B}$$

Table 1 shows the comparison between designs according to three standards for an example belt 2200 St2500 12:6 X: From this table, it is evident that the design conforming to International Standard EN ISO 15236 compared to Australian Standard AS1333 makes for a belt that is not just approximately 11% lighter and approximately 11% less expensive, but also makes it possible for the drive pulley diameter of a belt conveyor system to be reduced by 36 %. (Compare design conforming to AS1333 and “Based on EN ISO 15236 A2”). A slight increase of the cord pitch by 0.5 mm has a positive effect on the belt splice.

Standard for Design of 2200 St2500 12-6 X	Cord diameter ø, mm	Cord diameter ø, mm	Cord Pitch, mm	Cord Number	Effective Belt Breaking Strength, N/mm	Weight Difference, %	Ma Di
AS 1333	7.6	52	19.4	111	2624	100.7	
DIN 22131	6.8	41.2	15	144	2697	100.0	
EN ISO 15236 A1	6.8	41.2	15	142	2659	99.6	
EN ISO 15236 A2	5.1	26.6	10	214	2587	90.3	
Based on EN ISO 15236 A2	5.1	26.6	10.5	207	2503	89.6	

From this a general recommendation can be formulated for economical belt design: “In the case of belt design, a large number of thin cords should be preferred.” However, this rule only applies if the dynamic splice efficiency of the belt splices of at least 45%, which is required according to DIN 22101, is ensured. Often with long-distance conveyors having a center distance exceeding 1000 meters, customers require a higher dynamic splice efficiency of the belt splice than 45 %. This is especially applicable for long-distance conveyors having a center distance extending over several kilometers (often 10 km or more), where service lifes for a belt of 10 to 15 years are expected.

Steel Cord Conveyor Belts with and without Extra Low Loss Bottom Cover

In the design of a steel cord conveyor belt for horizontal long-distance conveyors (center distance exceeding 1000 m), the selection of the rubber compound for the bottom cover is of great significance. With the bottom cover made of a proper rubber compound, the indentation rolling resistance (IRR) can be significantly reduced. With long-distance conveyors, the IRR is responsible for 50% to 70% of the total resistance [5] (Fig. 2). This effect is strengthened with increasing center distance of a long-distance conveyor.

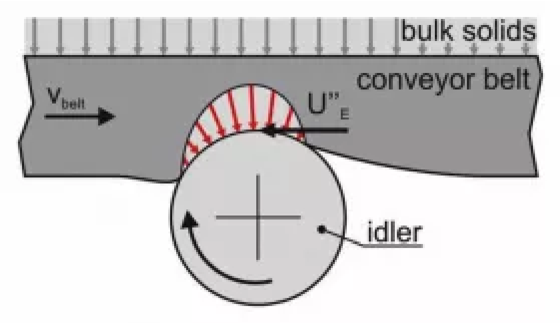

Fig. 3: Loss deformation of the bottom cover of a conveyor belt when running over an idler. (Picture: © Wennekamp [6])

The R&D department of Contitech is continually engaged in the further development of extra low loss conveyor belts with the rubber compound “XLL” (XLL = eXtraLowLoss). Thus, for example, Fig. 4 shows a 28% reduction in the required drive power from approx. 11 500 kW down to 8280 kW for a 5000 meter long horizontal conveyor with a conveying capacity of 30 000 metric t/hr at conveying velocity of 7.5 m/s when a modern XLL conveyor belt is used compared to the conveyor belt with the bottom cover made of a standard commercially available compound. This means for the example in Fig. 4 b, that:

- The emissions of CO_2 can be reduced by 32 523 metric tons/year (assuming the CO_2 emission coefficient for lignite of 1.153 kg/kWh and 24/7-operation per year consisting of 365 days).
- With the 3220 kW energy saved, up to 8955 private households can be supplied per year (assuming an average power consumption of one German household of 3150 kWh per year).
- EUR 1.41 million/year can be saved by a lignite power plant (assuming the average electricity generation costs of EUR 0.05/kWh in Germany).

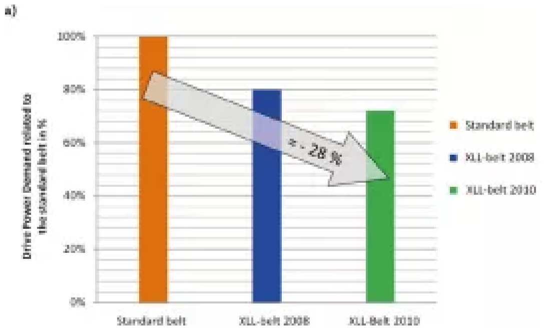

Fig. 4: Belt with extra low loss bottom cover “XLL” vs. standard commercially available conveyor belt – 28% reduction of the required drive power for the long-distance conveyor 5000 meters in length with a conveying capacity of 30 000 metric tons/hour. (Picture: © ITA, Leibniz University Hanover)

With the use of XLL rubber compound, not just the required drive power but the installed motor power can also be reduced. Due to the reduced motion resistance, a conveyor belt with a smaller nominal breaking strength than the conventional conveyor belt can be selected. As a result, the conveyor belt and the drive and tail pulleys of the belt conveyor system become “lighter” and more economical.

The end result is a belt conveyor system with a “lighter” and more economical conveyor belt, “smaller” motors or with a reduced number of motors, smaller drive and tail pulley diameters, a lighter tensioning device, and lighter steel construction, etc., which makes it possible to sharply reduce the costs for the entire system. Table 2 shows a feasibility study for a parallel OLC-2 long-distance conveyor at KPC mine (Kaltim Prima Coal), where the belt conveyor system is compared to a steel cord conveyor belt with and without a bottom XLL rubber compound. In [7], the OLC-1 long-distance conveyor was described well.

Parameters	**OLC-2 long-distance conveyor with a ContiTech XLL conveyor belt (current version)**	**OLC-2 long-distance conveyor with a ContiTech XLL conveyor belt (current version)**	**Difference Δ**
Required P_{erf} and installed P_{inst} drive power	P_{erf} = 3219 kW; P_{inst} = 4400 kW (2×2200 kW at the head end)	P_{erf} = 4970 kW; P_{inst} = 6600 kW (2×2200 kW at the head end and1×2200 kW at the tail end)	ΔP_{erf} = 1751 kW; ΔP_{inst} = 2200 kW (one additional drive)
Conveyor belt type, cord diameter d_S, nominal belt breaking strength k_N, and belt mass per meter m'_G	1100 St2250 5.5:5.5 X/XLL, d_S = 5.1 mm, k_N = 2250 N/mm, m'_G = 29.2 kg/m	1100 St2800 5.5:5.5, d_S = 6.3 mm, k_N = 2800 N/mm, m'_G = 34.3 kg/m	Δk_N = 550 N/mm, $\Delta m'_G$ = 5.1 kg/m

Required min. drive pulley diameter $D_{\text{Tr,min}}$	$D_{\text{Tr,min}} > 145 \bullet d_S \rightarrow D_{\text{Tr,min}} = 1000$ mm (according to DIN 22101 with the pulley load factor > 100%)	$D_{\text{Tr,min}} > 145 \bullet d_S \rightarrow D_{\text{Tr,min}} = 1250$ mm (according to DIN 22101 with the pulley load factor > 100%)	$\Delta D_{\text{Tr,min}} = 250$ mm
Max. belt tension during startup	$T_{\text{ANmax}} = 570$ kN	$T_{\text{ANmax}} = 684$ kN	$\Delta T_{\text{ANmax}} = 114$ kN

The OLC-2 long-distance conveyor at KPC in Indonesia transports 4000 metric tons/hour (nominal) and 4500 metric tons/hour (peak) of washed coal (bulk density of 0.9 metric t/m³) with a belt speed of 8.45 m/s. The conveying length is 12 589 m and the conveying height is 29.1 m. For this task, KPC as the user of the facility and PT RSSI as the EPC contractor selected the Contitech Stahlcord belt 1100 St2250 5.5:5.5 X/XLL with the extra low loss bottom cover. This selection is based on the successful application of the Contitech extra low loss belt with XLL-bottom cover in the existing OLC-1 back to 2002 and the expected improvements can be summarized as follows:

1. At the expected 15 year service life (assuming round the clock, i.e. 24 h/day and 365 days/year) for such a Contitech belt and the power difference of $\Delta P_{\text{erf}} = 1751$ kW, as well as the assumed electricity generation costs of $k_e = 0.05$ €/kWh, the following capital savings K are achieved: $K = 15 \text{ y} \cdot 365 \text{ d} \cdot 24 \text{ h} \cdot 0.05 \text{ EUR/kWh} \cdot 1751 \text{ kW}$ $K \approx$ EUR 11.5 millio
2. The belt amount ordered by KPC at 26032 m with a belt weight difference of $\Delta m'_G = 5.1$ kg/m, yields weight savings G of: $G = 26\,032 \text{ m} \cdot 5.1 \text{ kg/m}$ $G \approx$ 133 metric tons
3. Thanks to the maximum belt tension being reduced by $\Delta T_{\text{ANmax}} = 114$ kN (approx. 12 metric tons), the steel structure of the system, pulley shafts, bearings, etc. may be selected lighter and more economical.

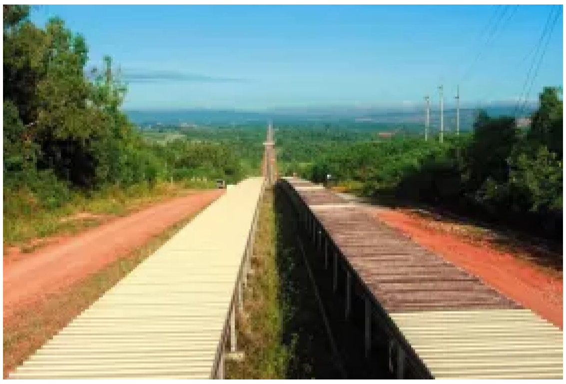

Fig. 5: Old OLC-1 and new OLC-2 long-distance conveyors positioned parallel to each other at KPC in Indonesia with XLL conveyor belts from Contitech. (Picture: © Contitech)

Thanks to the reduction in the number of motors (1×2200 kW), smaller pulleys, a lighter steel structure, as well as a conveyor belt with reduced nominal breaking strength and mass per meter, the initial procurement costs (incl. logistics costs) for the OLC-2 long-distance conveyor with an XLL conveyor belt are lower than the standard commercially available conveyor belt. Subsequent maintenance costs are lower as well, because “light” spare parts are less expensive.

Steel Cord Conveyor Belt Design acc. to Version 1982 and 2011 of DIN 22101

In 2011, the old standard DIN 22101 version 1982 “Belt Conveyors for Bulk Material – Principles for Calculation and Design” was replaced by a new version. The calculation example shown below illustrates the advantages for belt design that the new standard DIN 22101 version 2011 brings to the table.

DIN 22101 version 1982

According to DIN 22101 version 1982 (DIN 22101-1982), the minimum nominal breaking strength $k_{\mathrm{N,min}}$ of a belt is calculated according to Eq. (4):

$$k_{\mathrm{N,min}} = \frac{k_{\mathrm{sta}}}{1 - r_{\mathrm{verb}}} \cdot S_{\mathrm{sta}}$$

where the safety factor for normal operation and favorable operating conditions is $S_{\mathrm{sta}} = 6.7$ ($S_{\mathrm{sta}} = 9.5$ for unfavorable operating conditions).

Breaking strength loss value rverb for steel cord conveyor belts is a function of the number of steps of a belt splice:

- $r_{\text{verb}} = 0$ for number of steps $n \leq 2$ or
- $r_{\text{verb}} = 0.05$ for number of steps $n \geq 3$

For example, for a steel cord conveyor belt of width $B = 2100$ mm and maximum belt tension $T_{\text{max}} = 1000$ kN when in normal operation, the maximum belt tension k_{sta} is resulting in:

$$k_{\text{sta}} = \frac{T_{\text{max}}}{B} =$$

According to Eq. (4), this yields the minimum nominal breaking strength of a belt:

$$k_{\text{N,min}} = \frac{476 \frac{\text{N}}{\text{mm}}}{1-0{,}05} \cdot 6$$

For this numerical example, a standard steel cord conveyor belt St3500 is selected.

The breaking strength loss value is $r_{\mathrm{verb}} = 0.05$, because a steel cord conveyor belt St3500 has a three-step splice.

DIN 22101 version 2011

According to DIN 22101 version 2011 (DIN 22101: 2011-12), the minimum nominal breaking strength $k_{\mathrm{N,min}}$ of a belt is calculated according to Eq. (5):

$$k_{\mathrm{N,min}} = c_{\mathrm{K}} \cdot k_{\mathrm{K,max}} \cdot \frac{S_0}{k_{t}}$$

c_{K} is a coefficient for determining the minimum dynamic splice efficiency of a conveyor belt corresponding to the belt tension in the belt edge relative to the belt width. For steel cord conveyor belts, $c_{\mathrm{K}} = 1.25$ is for trough transition zones and $c_{\mathrm{K}} = 1$ for transition curves.

$k_{\mathrm{K,max}}$ is the maximum belt tension in the belt edge relative to the width of the belt, which is generally 1 to 1.2 times the mean belt tension.

The safety factor S_0 is a function of the features of splice manufacturing (competence of the splicers, quality of the splicing material, ambient temperature and conditions, etc.) whereas the safety factor S_1 is a function of the features of operating conditions (chemical/physical stress, rotational frequency, expected service life, starting/stopping cycles, etc.)

The safety factors are selected within the range of $S_0 = 1 \ldots 1.2$ and $S_1 = 1.5 \ldots 1.9$.

$k_{\mathrm{t,rel}}$ designates dynamic splice efficiency of the belt splice, which according to DIN for steel cord conveyor belts should be at least 45%. For all Contitech

“Stahlcord” steel cord conveyor belts, the relative reference fatigue strength of the belt splice is at least 50%!

Therefore, according to Eq. (5) for our numerical example (steel cord conveyor belt with B = 2100 mm belt width and maximum belt tension in normal operation T_{max} = 1000 kN resulting in the belt tension in the edge $k_{K,max} \approx 1.1 \bullet 476$ N/mm = 524 N/mm), the following minimum nominal breaking strength $k_{N,min}$ of a steel cord conveyor belt results

$$k_{N,min} = 524\,\frac{N}{mm}\cdot 1{,}25\cdot$$

For this numerical example, a standard steel cord conveyor belt St2500 is selected.

In this example, according to a new standard a significantly lower required belt nominal breaking strength results. This results in enormous cost savings for a belt which, depending on the cover ratio, can be around a third. Moreover, an St3500 requires a three-step splice, which is more complicated and takes more time to produce than a two-step splice of an St2500.

Transverse Reinforcement on the Impact Strength of a “Stahlcord Barrier” type Belt

Fig. 6: A typical belt in surface mining areas close to heavy mining machinery must often transport coarse and sharp-edged bulk material (a). A typical impact break with two affected steel cords (b) and the causes for this (c). (Picture: © Contitech)

A transverse reinforcement (of whatever kind) is generally incorporated in the top (carry side) cover of a steel cord conveyor belt in order to prevent impact breaks and the associated belt rips in the longitudinal direction and to protect the belt carcass (steel cord). Often these are belts used in heavy mining machinery or in short- and middle-distance belt conveyors in surface mining areas close to heavy mining machinery that are very heavily stressed by coarse and sharp-edged bulk material (Fig. 6).

The installation of a transverse reinforcement in long-distance conveyors (A-A > 1000 m) is also possible, but often is not worth it because of the higher manufacturing costs of a belt. Therefore, for long-distance conveyors, sensor loops with a spacing of 50 to 250 m are installed in the belt and dangerous points of the system (generally at the head end and tail end of the system) are equipped with rip detection systems. In this case, the feeding and transfer points should be designed so that insofar as possible no impact breaks can occur because a cord in the penetration point can come loose from the belt and completely jam an idler on the conveying route and can rip the entire belt. Even modern rip detection systems are useless when it comes to preventing such damage because they are often installed for cost reasons at the head end and the tail end of the system.

Fig. 7 shows possible steel cord conveyor belt designs with sensor loops, fabric and steel cord transverse reinforcement for protection of the belt. A fabric transverse reinforcement is generally used in practice for steel cord conveyor belts, although steel cord transverse reinforcements are also being used more and more, especially in the mining industry.

Within the internal research project, the impact strength, troughing properties according to ISO 703 and according to Conti procedures, ply adhesion of cover/transverse reinforcement and transverse reinforcement/bead core according to DIN EN 28094 were studied in Contitech’s test laboratories on a so called 3D-test rig for a steel cord conveyor belt that is typical in the German lignite industry, 2200 St2500 20:8 DIN-X, for two types of steel cord transverse reinforcement, for three types of fabric transverse reinforcement, and for 2 mm auxiliary rubber covers. The width of the transverse reinforcement here was approx. half the belt width, i.e. $B_{QA} \approx B/2$.

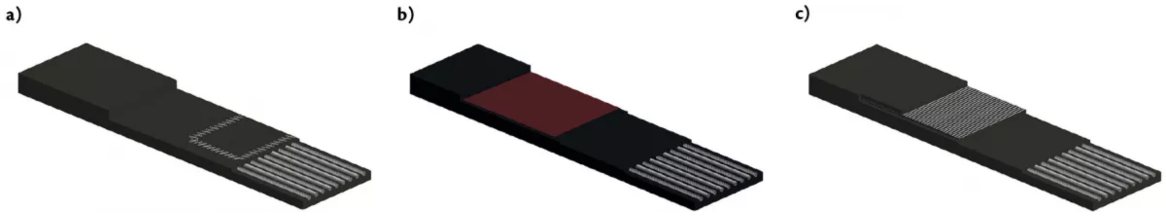

Fig. 7: Possible steel cord conveyor belt designs with sensor loops only (a), and with fabric (b) and steel cord (c) transverse reinforcement. (Picture: © Contitech)

With studies on the special Contitech 3D-test rig a belt sample undergoes multi-dimensional deformations to determine whether or not a steel cord transverse reinforcement creeps out from the top cover.

Fig. 8 shows a schematic diagram of an impact test rig, and Table 3 presents the results of the study where borderline impact energies and belt weights for various design variants of 2200 St2500 20:8 DIN-X are compared to each other.

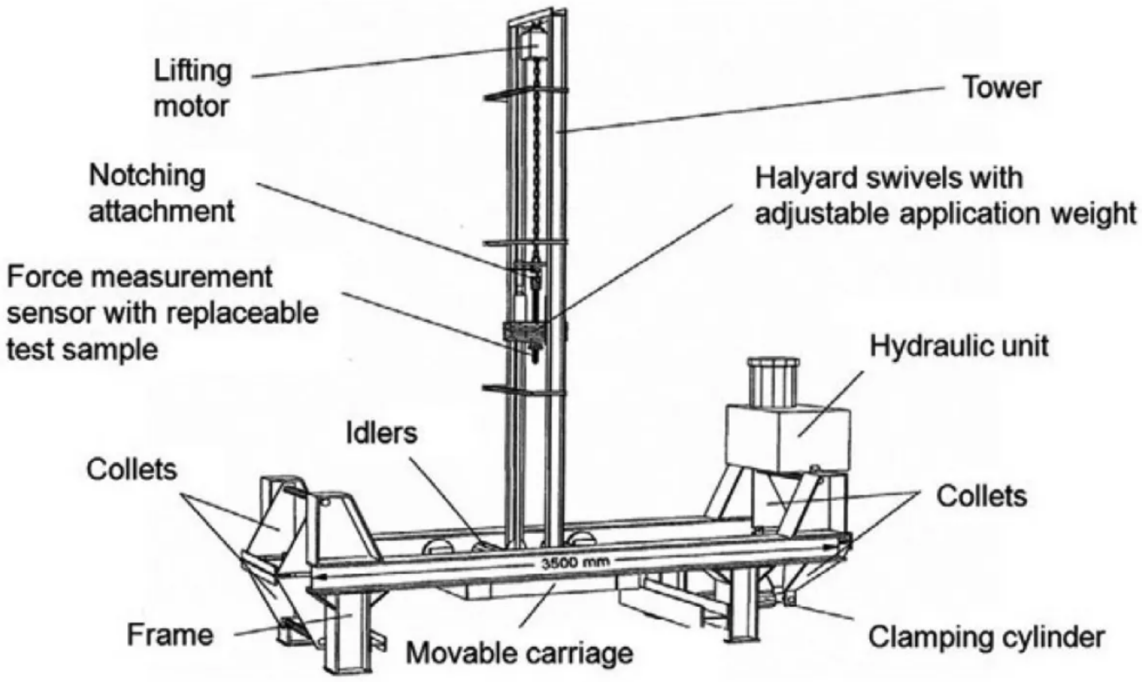

Fig. 8: Schematic diagram of Contitech’s impact test rig. (Picture: © Contitech)

Design	Reinforcement	Comparison of Weight, %	Comparison of Borderline Impact Energy, %
2200 St2500 20-8 X	No	100	100
2200 St2500 22-8 X	No	105	128

2200 St2500 20T-8 X	"Type 1" fabric	100	150
2200 St2500 20T-8 X	"Type 2" fabric	100	161
2200 St2500 20T-8 X	"Type 3" fabric	100	167
2200 St2500 20S-8 X	"Type 1" steel cord	102	222
2200 St2500 20S-8 X	"Type 2" steel cord	104	292

It is evident from Table 3 that a centrally arranged steel cord transverse reinforcement can increase the impact strength of a steel cord conveyor belt by a factor of two to three. The belt weight relative to width increases only slightly here.

For the new product Stahlcord Barrier the Type 2 steel cord transverse reinforcement was selected. Before approval of the product, it was also necessary to precisely test, in addition to the impact strength, the troughing according to ISO 703 and to Conti procedures, and ply adhesion of cover/transverse reinforcement and transverse reinforcement/bead core according to DIN EN 28094 on the 3D-test rig.

The advantages of the new product can be briefly summarized as follows:

- Two to three times more resistance to penetration damage. No belt rips possible in the steel cord transverse reinforcement area.
- Excellent troughability according to DIN ISO 703 and CONTI procedures (idler set test rig)
- High ply adhesion in accordance with ISO 15236 and CONTI procedures („3D“-test rig)
- Slight increase in the belt weight per meter of 5% compared to a steel cord conveyor belt without transverse reinforcement
- Long service live time à safer and more reliable operation of heavy-duty conveyor belts

Therefore, Stahlcord Barrier is an ideal solution for belts used in heavy mining machinery or in short- and middle-distance belt conveyors in surface mining areas close to heavy mining machinery and for transporting sharp-edged and coarse-grained bulk materials at several feeding and transfer points.

Conclusions

With increasing globalization, mining companies are also finding themselves under strong cost pressure. The investment plans in the mining industry are being adapted to the raw material market situation and were significantly reduced in many mining companies in 2014, for example, due to a lower world coal price. Therefore, it is essential for the survival of suppliers to the mining industry in particular to design their products in a cost-efficient and application-oriented manner without losing long service lives and proven quality characteristics of the product in the process.

On the other hand, a mining company can complete new projects through savings in terms of procurement and operating costs. Of course, environmental aspects are a point of focus both for suppliers in the mining industry and also for mining companies, not just because of the increased environmental requirements of the states but also by virtue of environment-oriented thinking, which has become corporate policy in many companies for some time now.