THE CASE FOR STANDARDISATION OF FLEXIBLE SIDEWALL POCKET BELTS

Graham Shortt

INTRODUCTION

The concept of a flexible side-wall conveyors has been around since the late 50's and early 60's. The idea, (like most good ideas), is very simple and there are many hundreds of applications of the technology around the world today.

Again, like most good ideas, this one was copied and there have been numerous court battles about copyright and principles almost since the invention of the system. Today, there are many suppliers of the flexible side-wall conveyor concept, all based essentially on the original Harbawell concept. However, even today, after about 40 years of use, the systems are still subject to a certain degree of mystery and many claims regarding the performance of the systems have been made, to a greater or lesser degree of truth.

The basic components of the system are:

1. a flat cross-stabilised plied fabric reinforced or steelcord belt,
2. the flexible sidewalls,
3. the attachments, which are in the form of cleats that are placed between the sidewalls, to form wells (hence the original name, which has become almost generic, of "flexowell"),
4. support systems (idlers) in order to carry the normal strand of conveyor and the return strand, particularly when the sidewalls are inset and the return support is by means of stub idlers, and
5. deflection systems, to allow the belt to be profiled, both by means of roller curves or deflection wheels.

Most suppliers of flexible sidewall pocket conveyors have attachments of a similar shape and size. The attachments are either vulcanised (both hot or cold) onto a prepared belt surface, or even moulded onto the belt. The major differences in supply are usually in the pitch and convolutions of the sidewalls, with the spacing of the cleats normally a multiple of the sidewall convolution pitch. In order to achieve some commonality between suppliers and by implication, an improvement in the design and understanding of flexible sidewall conveyors, a case is presented for the standardisation of the form and pitch of the sidewalls and cleats.

In addition, a case is presented for at least the standardisation of the designation of the belting. This is considered necessary so that designers and users are able to compare products for quality, price, performance and endurance, without having to resort to smoke and mirrors.

The design of the power and tensions for flexible sidewall pocket belts is similar to conventional troughed conveyors, with the exception of the determination of the system capacity, belt loading and the belt speed and belt width relationship. The basic tension determination as found in ISO 5048 may be applied, with some adaptation, in order to establish the system tensions and power in almost the normal way.

ATTACHMENTS - SIDEWALLS

The basic function of the sidewalls is to contain the material on the flat belt. The reason, then, for the convolutions, is to enable the belt to pass around pulleys and deflection stations, without tearing the sidewall apart. In addition, the sidewalls must be able to allow the belt to be deflected in the reverse, in order to allow the profile of the belt to be engineered to the requirements of the user. The usual maximum cleat height is determined as $h = 0{,}25 \cdot W$, where h refers to the sidewall height and W refers to the belt width.

The basic shape of the convolutions of the flexible side wall are in a characteristic concertina, or "S" shape. However, there are other shapes that have been used, with varying degrees of acceptance and success. Nevertheless, the essential requirement for designers is the pitch of the convolutions, because that enables the accurate determination of the cleat spacing and therefore, the capacity of the system.

Some of the basic forms of the sidewalls are as follows. In each case, P refers to the convolution pitch.

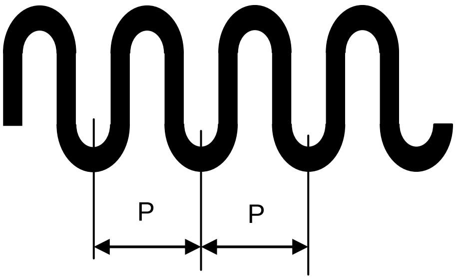


Figure 1: Typical S-Type Sidewalls

However, even the humble "S" has different shapes. An example of such a variation is shown below.

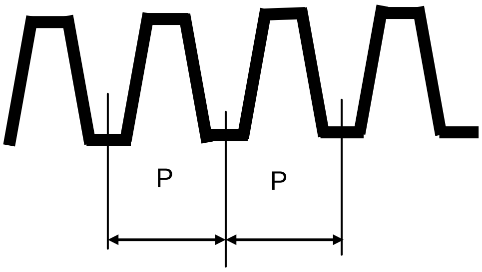


Figure 2: Variation Of "S" Profile

It becomes even more interesting when we consider the "original" Harbawell profile, which is termed either "M" or "W". Of course the M could be seen simply as an up-side-down W.

For example:

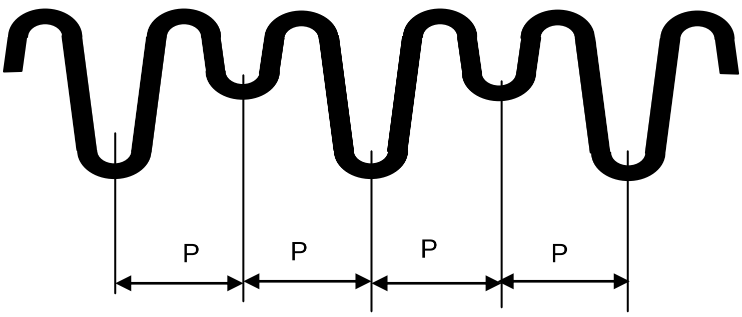


Figure 3: Typical Sh –Type

In this case, the convolution pitch is effectively twice the "normal" pitch for an S profile.

An alternative for this may be

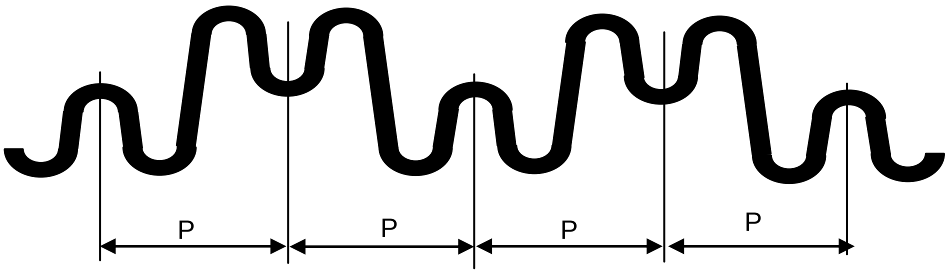


Figure 4: Typical Shd –Type Sidewalls

Again, the actual convolution pitch is difficult to identify. These two profiles are not very common. However, they are often specified in South Africa.

Even for the “standard” S profile sidewalls, a comparison of pitches is confusing. The table below shows that, while the convolution pitches are close, they are not the same, even allowing for conversion from metric to imperial measure.

Sidewall height	SUPPLIER				
	A	B	C	D	E
60 (2½”)	40	41	42	40	42
80 (3”)	40	41	42	40	42
100 (4”)	40/50	41	42	40	42
120 (5”)	50	41	42/63	40/60	60
160 (6”)	60	41	63	60	60

Table 1: Sidewall Height Vs Pitch

Many suppliers also specify a 140 mm cleat height and indeed, this is a popular size. However, a basic requirement is that the cleat should never be the same height or project beyond the sidewalls. For this reason, the 140 mm sidewalls should not be used. As can be seen, some suppliers specify two pitches for the same sidewall height and this can only lead to further confusion.

From the table, it is clear that there appears to be no standard pitch for the sidewall convolutions. As noted earlier, it becomes impossible for the user or the designer to compare systems when there is no comparison. The standardisation of the convolution pitch, irrespective of the form of the convolutions, can definitely form the basis of standardisation.

In addition to the convolution pitch, the width of the sidewall is very important for the correct determination of the inset, when the belt is required to traverse reverse bends. Again a set of comparisons is very revealing.

Sidewall base width	SUPPLIER				
	A	B	C	D	E
60 (2½”)	50	2”	50	50	50
80 (3”)	50	2”	50	50	50
100 (4”)	50	2”	50	50	50
120 (5”)	50	2”	50/75	90	50
160 (6”)	50	2”	75	90	75

Table 2: Sidewall Base Width Vs Sidewall Width

As can be seen, the base width which is normally about 3 mm - 5 mm wider than the sidewall itself also has a rather interesting spread of values. Again, it is clear that there is no standard base width for the sidewalls.

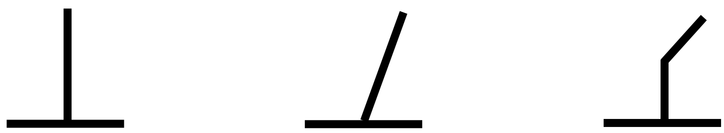
ATTACHMENTS - CLEATS

The capacity of a flexible sidewall pocket system on a steep incline is achieved by the application of cleat attachments to the belt surface, with the cleats running between the sidewalls, thus forming pockets.

Most suppliers of flexible sidewall pocket conveyors have attachments of a similar shape and size. However, the nomenclature for the different cleat forms is apparently unique to almost each suppler. As demonstrated, the major differences in supply of the sidewalls are usually in the pitch of the convolutions of the sidewalls, with the spacing of the cleats normally a multiple of the sidewall convolution pitch. The determination of the correct spacing of the cleats therefore becomes very difficult when the cleats and sidewall pitches are not standardised.

The geometry of the attachment cleats is very similar (for the majority of suppliers in South Africa) with minor differences only. This is a second area where standardisation would be very helpful for the users and designers of flexible sidewall pocket belts. Of particular interest would be the profile and convolution pitch of the sidewalls. Even then, the actual profile of the sidewall is not as important to the designers as the convolution pitch.

For inclined belts, there are generally three types of cleat available, namely the “T” cleat, the “C” cleat and the “TC” cleat (sometimes also referred to as “S”), which is a combination of both T and C cleats.



“T” Cleat “C” Cleat “TC” Cleat

The height of the cleats is generally as follows, for a very narrow range.

Cleat	CLEAT HEIGHT						
T	55	75	90	110			
C	55	75	90	110	140		
TC (S)		75	90	110	140	180	220

Table 3: Cleat Height

American systems have similar cleat heights, expressed in imperial units. Of course, the list shown is not exhaustive and is extended both upwards and downwards by nearly all the suppliers' literature consulted.

Again, standardisation of the basic form and height of the cleats will improve the understanding and design of these systems.

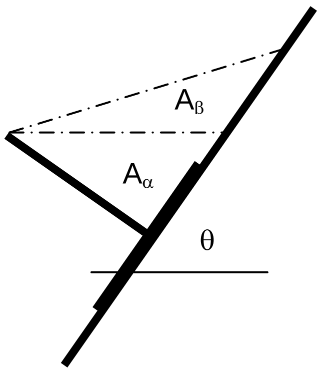
BELT SPEED

The determination of the belt speed and belt width is based on the capacity of each individual pocket. The capacity of each pocket is determined by the full loading of the pocket, which consists of

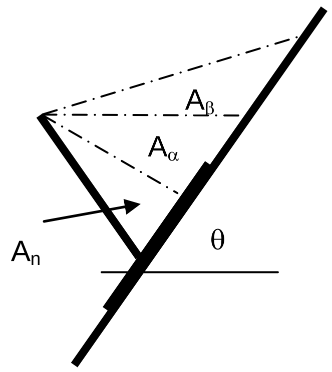
1. The “water-line” area of the pocket A_n
2. The slope “water-line” area A_α

3. The surcharge area A_β

The basic area for the different types of cleats may be represented as follows.

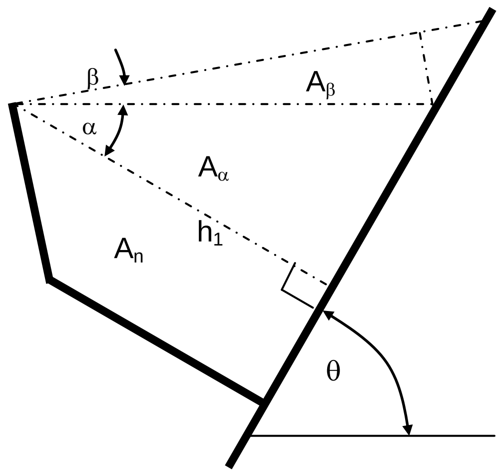


"T" Cleat Filling



"C" Cleat Filling

In the case of the T cleat, $A_n = 0$



TC Cleat Filling

With reference to the sketch:

θ Angle of inclination of the belt
α 90° - θ (Slope water–line) (Reference)
β Surcharge angle of material

The value of the water-line area A_n is normally provided by the supplier. In the author's experience, only two suppliers have made the capacities available and only by inference can one obtain the water-line areas.

Average values of A_n for TC and C cleats are as follows:

TC Cleat Water-line Area (m²)	
TC75	$1,63 \times 10^{-3}$
TC90	$2,33 \times 10^{-3}$
TC110	$3,50 \times 10^{-3}$
TC140	$4,72 \times 10^{-3}$
TC180	$8,80 \times 10^{-3}$
TC220	$12,0 \times 10^{-3}$

Table 4: TC Cleat water-line area

C Cleat Water-line Area (m²)	
C55	$0,55 \times 10^{-3}$
C75	$1,02 \times 10^{-3}$
C90	$1,47 \times 10^{-3}$
C110	$2,20 \times 10^{-3}$
C140	$3,57 \times 10^{-3}$
C180	$5,90 \times 10^{-3}$

Table 5: C Cleat water-line area

The use of TC 160 cleats is not normally encouraged. This cleat is usually made up from a cut-down of a TC180 cleat and often the area A_n for the TC160 is lower than the TC140 cleat.

As can be readily seen, standard values (within a small tolerance band) for the water-line areas would be of great value to the designers, since the user will be able to truly compare products from different suppliers.

CAPACITY OF CLEATED BELTS

C cleats deeper than 140 are not often used. As can be seen, the TC cleat has a water-line area approximately 60% greater than the C cleat of the same depth.

The incline water-line area is determined with reference to the belt inclination and is given by $A_\alpha = \frac{h_1^2 \cdot \tan\alpha}{2}$ m², where h_1 refers to the cleat height.

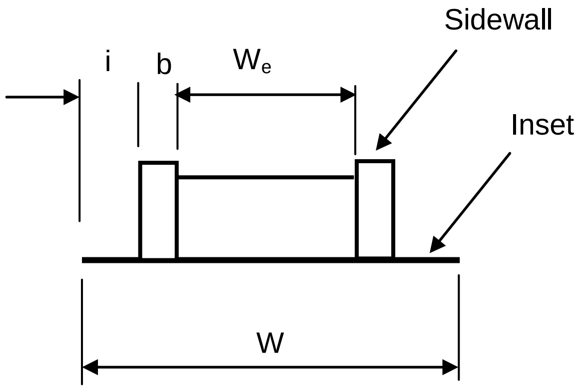
The surcharge area is determined by $A_\beta = \frac{h_1^2 \cdot \sin\beta}{2 \cdot \sin\theta \cdot \sin(\theta - \beta)}$ m².

The total area is then found by $A_{100} = \left(A_n + A_\alpha + A_\beta\right)$ m²

The capacity of each pocket is therefore $\left(A_{100} \cdot W_e\right)$ at 100% filling. Note that the pocket filling should not exceed about 70% of the area, depending on the material characteristics.

The cleats are normally spaced along the belt in multiples of the sidewall convolution dimensions, with the cleat usually butting against the male part of the convolution, rather than being set against the female part of the convolution. This dimension should be obtained from the supplier and, if the convolutions are standardised, the dimensions could be simply

obtained from the relevant standard, without having to juggle supplier's catalogues, or trying to pull hen's teeth.
With reference to the sketch, W_e is the effective width of the pocket and is related to the belt width by the inset (as required) and the sidewall width. Thus $W_e = W - (2 \cdot b) - (2 \cdot i)$.



The capacity of the conveyor can be determined by $C_{dc} = \dfrac{3600 \cdot \eta \cdot A_{100} \cdot W_e \cdot S \cdot D}{\ell}$ t/h

Where

C_{dc}	Design Capacity	t/h
A_{100}	Area at 100% as determined above	m²
η	Percentage loading	
W_e	Effective width	m
S	Belt speed	m/s
D	Material bulk density	t/m³
ℓ	Cleat spacing	m
i	Inset	m

ATTACHMENTS – STUB IDLERS

In the South African context, stub idlers should be specified to use tubing diameters in accordance with SANS 1313/1, namely, 102 mm, 127 mm and 152 mm and normally bare steel shells are preferred. The stub idlers must be designed with a smooth, flat domed end and the bearings could be specified as double-sealed units, to prolong the idler life as far as possible. The stub idler must be subject to the same T.I.R requirements as conventional idlers. The length of the idler roll is generally a function of the inset dimension on the belt edges. In turn, the inset dimension is determined in accordance with the system tensions.

A useful rule of thumb that is applied is that the inset dimension should be $i = 0{,}1 \cdot (W + h)$ m each side, to maintain proportions. However, the inset must also be determined from the tension requirements and the greater of the two dimensions must be used in the design and in the determination of the effective width W_e.

The belt class is determined from the tension in the normal way,

i.e. $T_b = \dfrac{T_{max} \cdot F_x}{2 \cdot \eta \cdot i}$ kN/m width.

In this case,

T_b = Belt class designation (SANS 1173, SANS 971 and SANS 1366)
T_{max} = Maximum system tension at the reverse curve kN
F_x = Belt factor of safety (10 for plied fabric and 6,67 for steelcord)
i = Minimum inset dimension N
η = Fraction of inset to allow clearance. Normally 0,8 is applied.

The carrying idlers are usually standard SANS 1313/1 flat idlers and the stringer centres will be set accordingly. The length of the stub idler must then be at least the difference between the belt width and the stringer, plus a minimum of 80% of the inset dimension. The stub idlers are usually declined at about 5°. A typical stub idler may be as illustrated below.

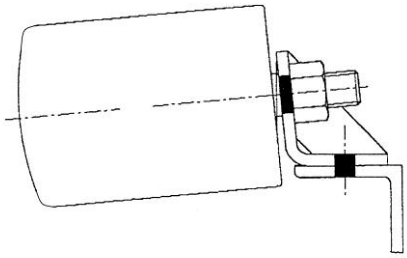


Figure 5: Typical Stub Idler

ATTACHMENTS – DEFLECTOR WHEELS

Deflector wheels are used to change the vertical direction of the belt and are distinct from pulleys in that they consist of two narrow wheels on a single axle. When the belt is deflected inwards, the sidewall convolutions will concertina together. If the deflection mechanism is not correctly dimensioned, there is the danger of the sidewalls bunching and bulging outwards, to be destroyed by contact with the supporting steelwork or simply torn from the base belt.

The normal proportion of the deflector is to set the diameter at 4·h for inward deflection, where h refers to the sidewall height. However, this must be approached with some circumspection. The wheels could be fitted with internal bearings in a hub, running on a dead shaft, or they could be fixed to the live shaft, which will be supported in bearings in the normal way. The deflector wheels are normally dimensioned to suit the diameters given for inward or outward deflection of the sidewalls and the diameters are usually obtained from the suppliers. For the sidewall heights as considered earlier, typical minimum diameters for inward and outward deflection of the sidewalls is given. These diameters are independent of the diameter requirements for the belting carcass and construction and obviously the greater of the diameters as determined will prevail.

As can be seen from the table, while the diameters for the various sidewall heights are similar, they are sufficiently different to create confusion. Again, the differences make design and operational comparisons very difficult, if not impossible.

Sidewall height	MINIMUM DIAMETER FOR INWARD DEFLECTION BY SUPPLIER					
	A		B		C	
	Diameter	Ratio	Diameter	Ratio	Diameter	Ratio
60 (2½”)	240	4	10”	4	250	4,16
80 (3”)	320	4	16”	5,33	350	4,38
100 (4”)	400	4	18”	4,50	400	4
120 (5”)	480	4	20”	4	500	4,16
160 (6”)	640	4	24”	4	630	3,94

Table 6: Minimum diameter for inward deflection by supplier

In this case the ratio refers to the ratio of the deflection wheel diameter to the sidewall height.

PULLEYS

In contrast to the inward deflection, the outward deflection of the sidewalls must be limited to the maximum safe extension of the convolutions as they stretch over the pulley. If the pulley or deflector is too small, the sidewalls will try to straighten out and this will result in the sidewalls tearing from the top downwards. The resulting spillage has to be seen to be believed.

In the case of outward deflection, the ratio is not that clear. Apart from the diameter of the pulley as determined from the belt carcass thickness (excluding any cross-stabilising plies in steel cord reinforced belt) in accordance with ISO 3684, the most important factor determining the pulley diameters is the requirement that the profiles must be able to flex through the bend without tearing or buckling, as noted earlier. There is no real ratio that has been published regarding any rule of thumb, as for inward deflections. The ratio R shown in the table is derived in each case and could form the basis of a standard.

Sidewall height	MINIMUM DIAMETER FOR OUTWARD DEFLECTION BY SUPPLIER					
	A		B		C	
	Diameter	Ratio	Diameter	Ratio	Diameter	Ratio
60 (2½")	150	2,5	6"	2,4	200/250	3,33/4,16
80 (3")	200	2,5	8"	2,66	200/250	2,5/3,13
100 (4")	250	2,5	10"	2,5	250/315	2,5/3,15
120 (5")	300	2,5	12"	2,4	315/400	2,62/3,33
160 (6")	400	2,5	14"	2,33	400/500	2,5/3,13

Table 7: Minimum diameter for outward deflection by supplier

In this case the ratio refers to the ratio of the pulley diameter to the sidewall height. From the table, it appears that a common ratio is 2,5 but variations are quite wide.

Once again, the table (taken from a random selection of well-known suppliers) shows that there is very little commonality or even agreement between the suppliers. This again creates confusion and makes design or operational comparisons almost impossible.

It must be noted that the pulley diameters shown are based on the requirements of the sidewalls only. The requirements of the belting must be considered in addition to this.

BELTING

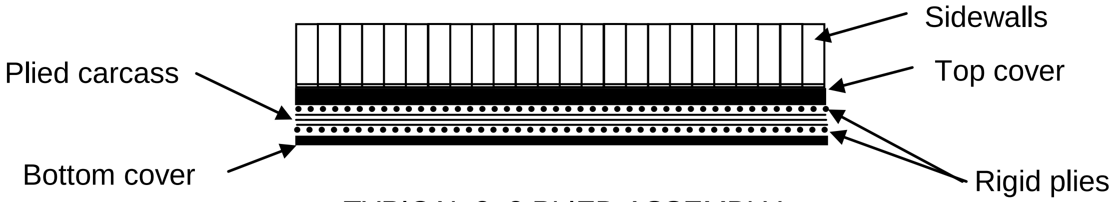
The belting that is used for flexible sidewall pocket systems follows the belt widths and classes given in SANS 1173, SANS 971 and SANS 1366. In the author's experience, solid woven belting has never been specified in a cross-rigid construction. However, that does not preclude such a specification and it would be interesting to see the results of such a specification.

The belting consists of a carcass, which can be multi-plied textile (EP) or steelcord, with transverse reinforcing. The transverse reinforcing creates the cross-stabilised or rigid belt, that will not easily deflect across the weft. This is necessary to prevent the belt from deflecting unduly when it is deflected by means of a roller curve using stub idlers, or a deflecting wheel set. This is particularly important when considering the belt strength as a result of the inset, as noted earlier. In addition, the return strand of an inset system is carried on stub idlers and the belt is therefore supported along its length by the inset, which must not deflect too severely.

The reinforcing may be laid under the top cover, or under the bottom cover of the belting. Alternatively, it may be laid on both sides. There is a great deal of confusion regarding the specification of the cross-rigid ply, with various constructions being offered for "light duty", "heavy duty" or "normal duty", none of which are adequately defined.

The belt covers are usually offered as 4×2, with the heavier cover on the carrying side. Since the material is essentially at rest in the pocket (excepting for minimal movement through curves), very little cover wear is normally experienced and the belts can last for extended periods, with normal maintenance.

For belts with a single cross-reinforcing ply, it is suggested that the rigid ply is placed under the top cover, since the inset will allow the belt to be deflected upwards. In this case, the designer will want to minimise belt weft deflection at the inset, to ensure system stability.



TYPICAL 3+2 PLIED ASSEMBLY

The alternative (and this appears to be rather common in the South African context) would be to specify 2 rigid plies, located top and bottom of the carcass, for a very cross rigid belt, while still maintaining warp flexibility. Again, there is very little commonality amongst the suppliers, with each having their own designation, with no standardisation. This once more makes design and operational comparisons almost impossible.

CONCLUSION

As a result of the large number of suppliers, all with independent and often conflicting technologies, ideas and internal standards, the correct and interchangeable design of flexible sidewall pocket conveyor belts is often very difficult. In many instances, the suppliers of the equipment so arrange their internal standards that, irrespective of the performance of the equipment, the user (who, after all, paid for the equipment) has no recourse to comparative pricing or maintenance. For this reason, the standardisation of the sidewall convolution pitches, together with the standardisation of the sidewall base width and the convolution width will greatly simplify the design and selection of this equipment. In addition, the standardisation of at least the general range of cleats (from about 60 mm up to and including 220 mm high), together with a toleranced range of associated water-line areas will again simplify the design of the systems.

Finally, the standardisation of the nomenclature for the belting is essential.

Dimensional standardisation is often considered as an opening of the flood-gates for low-quality equipment. However, as was the South African experience with the initial dimensional standardisation of conveyor idlers and rolls, the cream will rapidly rise to the top and the overall quality of the design and operation of flexible side-wall pocket conveyors will improve.

Standardisation does not imply the surrender of proprietary knowledge, since the construction and quality of the equipment is generally improved by the use of standardisation. In addition, interchangeability of equipment will allow users and designers to select equipment that best suits their designs, their operational requirements and their budgets.

AUTHOR'S CV

GRAHAM SHORTT

Graham Shortt retired from Anglo American in 2006, after 25 years service in the materials handling section of Specialized Engineering. However, he still endeavours to remain active in the field of materials handling, especially belt conveyors. He has approximately 33 years design experience related to belt conveyors and materials handling.

Mr Shortt obtained a Master of Engineering Practice (Bulk Solids Handling) from Tunra in Australia and is also a Fellow of the South African Institute of Materials Handling. He was granted the CMA Award for Excellence in Belt Conveying in 2006 and is an Honorary Member of the CMA.

AUTHOR ADDRESS

Graham Shortt
P. O. Box 3297
Kenmare
1745
Republic of South Africa