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GEOMETRICAL AND MECHANICAL PROPERTIES OF STEELCORD BELT SPLICES

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1. INTRODUCTION

It has been recognised that the belt splice is the weakest link of a conveyor belt. This is mainly due to the following factors :

- the splice forms a discontinuity in the tension-transmitting members of a belt

- forces are no longer transmitted by steel cords only but also surrounding rubber

- the distribution of forces within a splice is no longer uniform.

Safety factors commonly applied during belt selection attempt to prevent a possible loss of splice strength during service. In principle the life of a splice should be as long as the parent belt but this is very often not achieved for the following reasons :

(a) the abovementioned safety factors take operational conditions into account rather than mechanics of the splice.

(b) the site execution of splices is heavily dependant on quality of workmanship (both in general and detail).

Over the years, overseas research centres have been involved in projects which aimed at better understanding of splice behaviour, possible mathematical modelling and the improvement of the long term strength of the splice.

Many of those findings have found their way into industrial practice and/or proposed standards.

However South Africa still lacks even basic standards dealing with the issue of steel cord splices, the choice of pattern and splice quality. The only available standard SABS 1366 deals with overall quality of steel cord belting and is of extremely limited value when it comes to evaluation of splices.

2. SPLICE PATTERN

Splice pattern is governed mainly by the belt strength and ranges between single-step to multi-step. Progressively as belt strength increases the number of steps is also increased.

In most cases standard patterns as recommended by available literature are being utilised (at least in theory). Sometimes new, non-standard patterns are utilised mainly to achieve increased long term strength of the splice.

The fact that a so-called standard pattern of splice is being used does not guarantee that the required strength (both long term and short term) will be achieved.

One of the most crucial points is the maintenance of a gap between cords. This is very often dismissed as a pure geometrical factor without any influence on splice performance. The opposite is in fact the case. Transmission of forces in the splice from cord to cord occurs through the rubber surrounding the cords.

Rubber stresses are directly proportional to angle of distortion of rubber and are defined as follows :

$$\tau = G \cdot \gamma$$

where G - shear modulus
γ - angle of distortion
τ - shear stress

Under load, cords within the splice will shift, creating angular deformations of surrounding rubber. This deformation and resulting shear stress will be higher for cords closer together. In addition for each pair of cords, the shear stress will not be uniform but will have a maximum value for the points closest together and decreasing above and below as a result of increase in gap due to the circular shape of the cords in section.

As the level of shear stresses in rubber also reflects the ability to resist cord pull-out (i.e. the higher the stresses the lower the pull-out force) it is required that the gap between the cords in the splice area remains as wide as practically possible. In addition, the biggest ratio between the gap and cord diameter should be strived for.

Practical limits are imposed by the fact that the number of cords in the region of the splice is increased and this requires even greater care to ensure maintenance of correct gaps during splicing.

From available information it appears that currently used splices allow for a $^g/_d$ ratio between 0,25 to 0,5 or, conversely, a ratio between cord spacing and cord diameter of 1,25 to 1,5.

For example for an 8mm diameter cord and 11,3mm spacing in the splice area, the above ratios result in maximum and minimum gaps of 4 and 2mm respectively.

The above values will place strict limits on the position of cords, their straightness and inter-spacing. While talking about splice pattern it is important to mention that various layouts of edge cords may either improve or worsten overall performance of a splice.

3. GAP BETWEEN CORD ENDS IN THE STEP AREA

In multi-step splices, the number of cords are cut short and meet each other in the step area.

The gap between cord ends is frequently the source of dispute between supplier/splicer on the one side and end-user on the other.

Despite the fact that certain guidelines are available during the splicing process, these gaps have been found to vary between 0 to 30mm and more. To add to the problem, cords are very often cut in a careless manner by the splicer.

While the importance of maintaining a gap between cords is axiomatic, the influence of the gap between ends of cord is not clear-cut.

Simulations performed on a computer programme adopted for the purpose of splice modelling and evaluation showed the following result :

- the function defining the relationship between axial force in rubber and gap length is of a non-linear character.

- the boundary value of such a gap seems to be 3,125 x cord diameter. By increasing the gap beyond that point, the reduction of the axial force is practically not that significant, however desirable it may be. A decrease of the gap below the boundary value produces a rapid increase in axial force in the rubber between cord ends.

The specified value of 3,125 x cord diameter is incidentally very close to that indicated in foreign literature (namely 3 x cord diameter).

In the abovementioned model used for evaluation, it was assumed that adhesion forces between rubber and cord end are equal to those which can be transmitted by the rubber. Unfortunately this is not the case and in fact adhesion values in this area is difficult to define for the two following reasons :

- in the area of the cut cords wires have been exposed

- cut is very often of poor quality

As continuity of the system is desired, it is beneficial to lower axial forces in the end gap area to such an extent that separation of rubber and cords can be avoided. This can only be achieved by increased end gaps.

4. CORD STRAIGHTNESS

This is possibly the most common currently fault found in steelcord belt splices but more often than not this is simply ignored.

It must be remembered that at least two things happen when a cord or number of cords within a splice area are out of alignment :

- gaps between cords are changed and very often reduced below acceptable values

- under tension, the splice becomes distorted, creating new patterns of internal forces

None of these can be ignored if proper mechanical behaviour of the splice is required.

The problem of decreasing the side gaps has already been discussed in the previous paragraphs.

We have attempted to simulate a splice on a computer model where particular cords are shifted out of alignment. Both change in internal forces (in rubber and cords) could be noted but it was also seen that the splice was forced into a curved shape sideways by a value exceeding the original curvature of the non-aligned cords.

At this stage it seems that as far as cord straightness is concerned, each case should be evaluated individually as results will be affected both by overall number of cords and splice pattern as well as the number and pattern of curved cords.

5. CONCLUSIONS

From the abovebrief review it is obvious that proper application of not only rubber technology but also purely geometrical aspects of the splice will affect the long-term performance of that splice.

At this point in time, the accuracy of the geometry of a splice is not treated seriously enough.

The authors feel strongly that a proper specification for steel cord belt splices should be drawn up and either added as an Appendix to a revised SABS Standard 1366 or issued as a separate new standard.

It is considered imperative that proper reference be made to limits for gaps between cords and cord ends as well as limits for alignment of the cords.

ACKNOWLEDGEMENTS

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REFERENCES

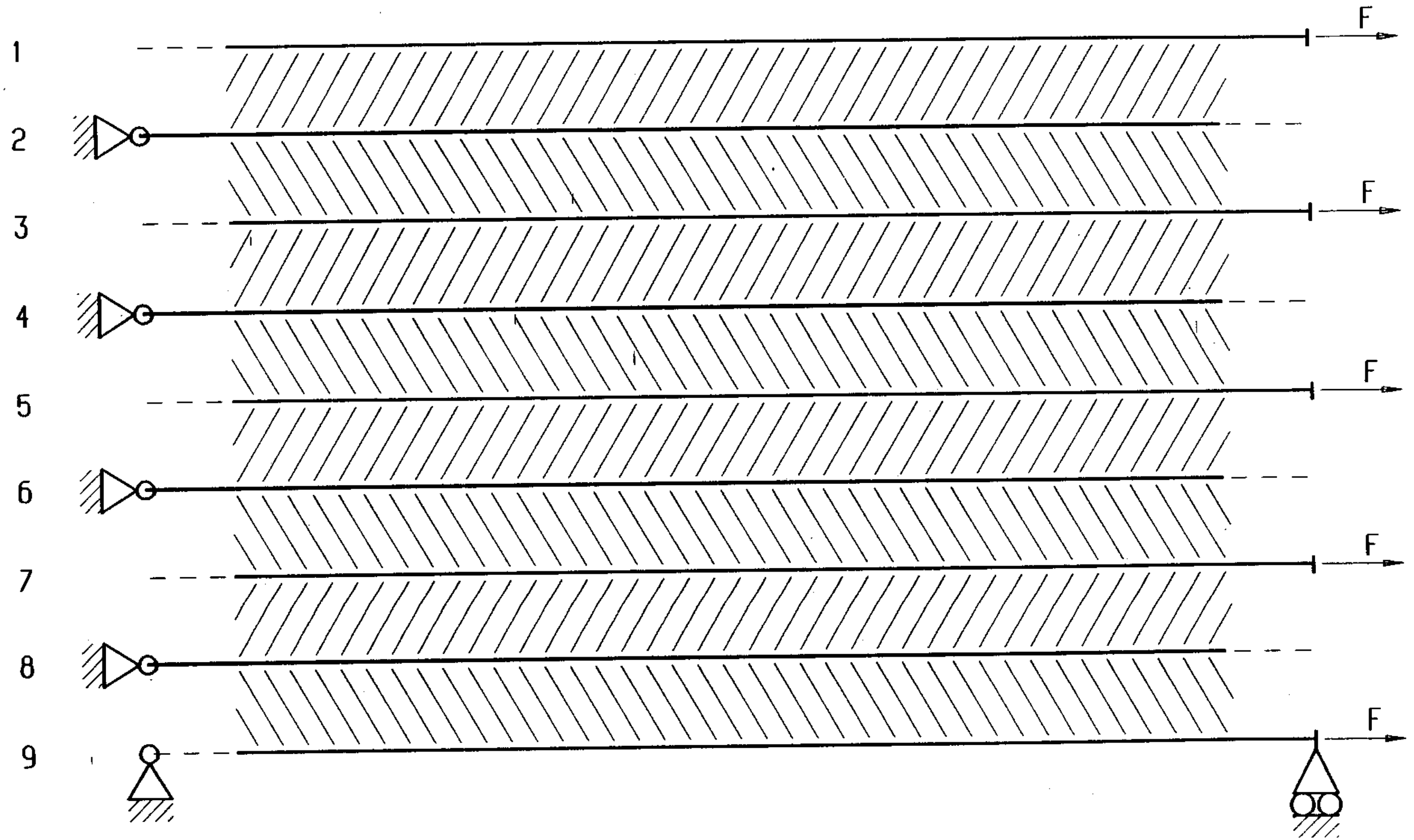
1. Kakuda M. Performance Required for Steelcord Conveyor Belts Core Rubber : Bulk Solids Handling, Vol 3 (1983) No 3 pp. 463-467

2. Flebbe H. Dynamic Splice Strength - Design Criterion for Conveyor Belts ? Bulk Solids Handling, Volume 8 (1988) No 5 pp. 581-586

3. Oehmen K.H. Edge Effects on the Strength of Steel-Cable Belt Joints (in German) Braunkohle Vol 1/2 (1986) pp 17-22

4. Keeve Steyn Inc - Internal Reports

5. Computer Splice Model



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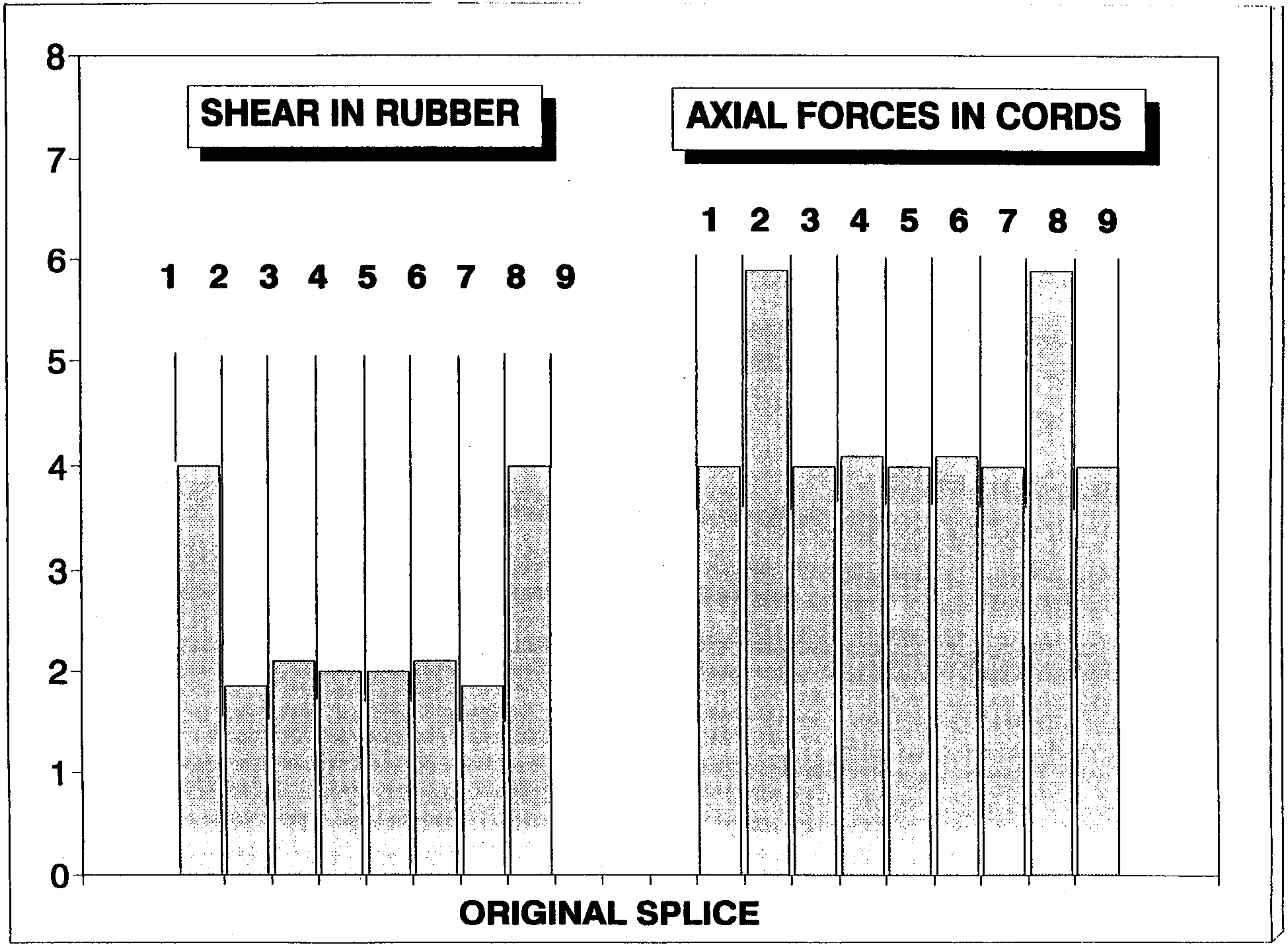
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AXIAL FORCES IN CORDS
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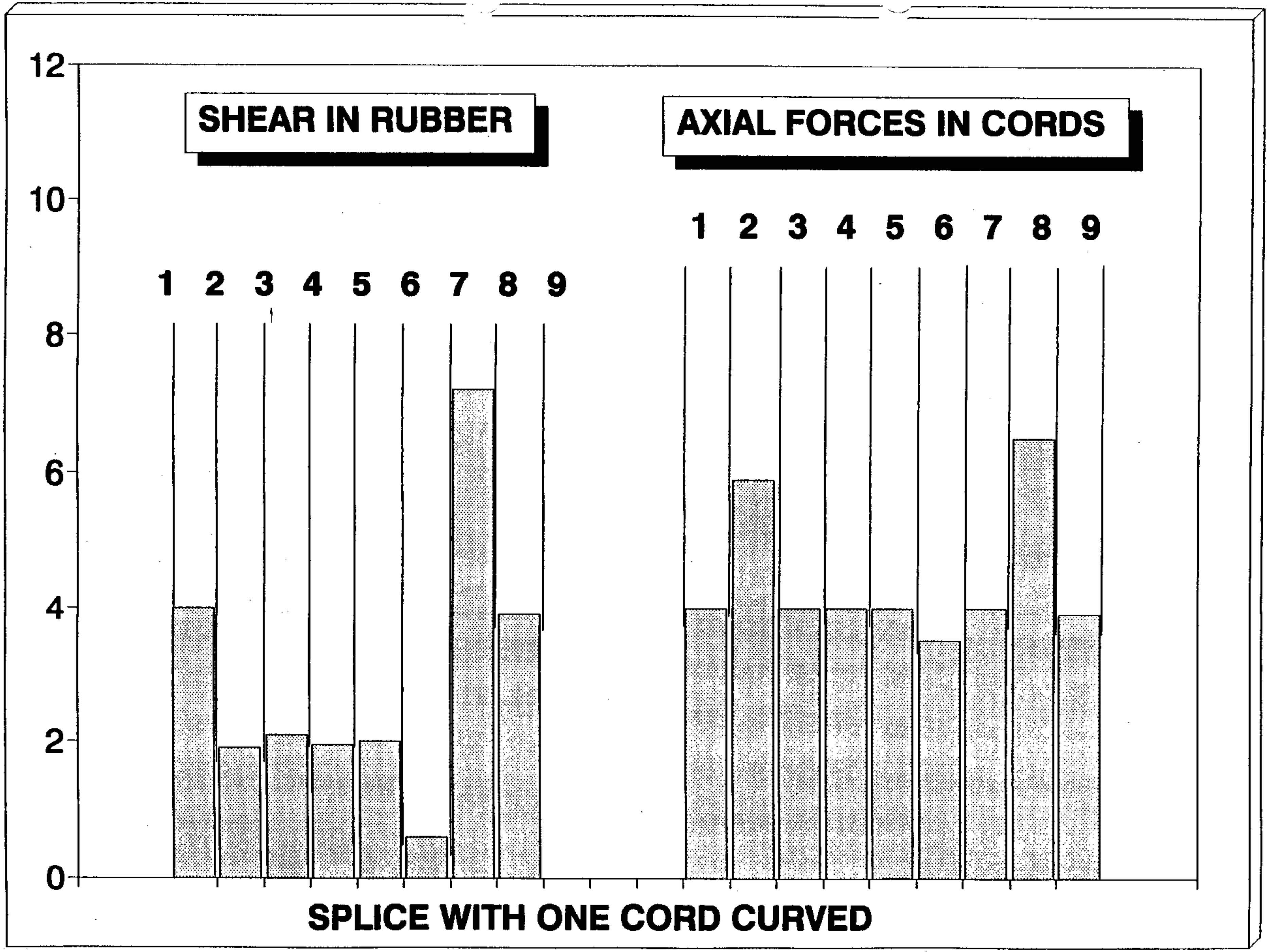
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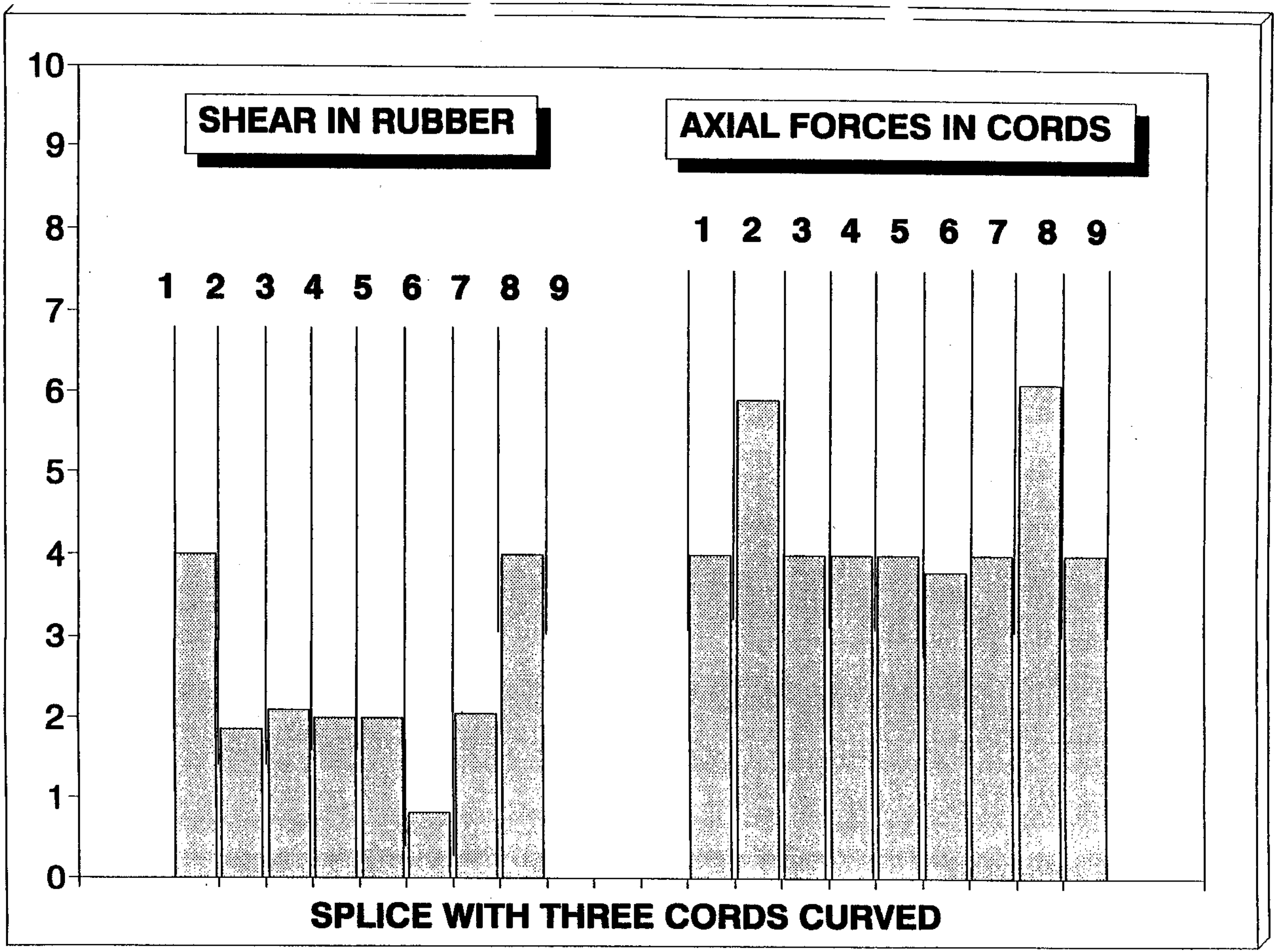
SPLICE WITH ONE CORD CURVED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AXIAL FORCES IN CORDS
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SPLICE WITH THREE CORDS CURVED