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RESULTS OF A BACKFILL MONITORING PROGRAMME
AT VAAL REEFS 5 SHAFT

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COMPLETE BACKFILL RIB
SHRINKAGE

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PREFACE

Backfill is used as an important component of stope support in South African gold mines, particularly with respect to the alleviation of falls of ground and rockburst damage. To ensure that backfill is able to achieve this objective most effectively, it is necessary that it be placed as close to the face as possible and is used in conjunction with good face area support. However, of equal importance is the need to ensure that the backfill placed is designed to achieve minimum porosity on placement. This is essential if shrinkage is to be minimized. Shrinkage can also be reduced if the placement of the fill is done slowly and is followed by careful topping up. This in turn requires good supervision of the team responsible for placing the backfill.

In this report the effect of shrinkage on the in situ stress-strain behaviour of a classified tailings backfill is documented and it is shown that excessive shrinkage severely reduces backfill stress levels, which in turn adversely affects the benefit of backfill as local face area support.

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SUMMARY

This report documents the results of the in situ measurements carried out in the 68-52 stope at Vaal Reefs 5 Shaft. The in situ stress-strain behaviour of classified tailings backfill has been measured in panel P3. There is good agreement between in situ measurements and laboratory determined confined compression results for backfill with a porosity of 43 per cent. The complete backfill rib behaviour which has been determined for this location is similar to the behaviour observed at other mines. An excessive amount (four to seven per cent) of shrinkage is indicated by the results and this has led to low backfill stress levels and a reduction in face area support benefit.

CONTENTS

LIST OF FIGURES	(iv)
1 INTRODUCTION	1
2 IN SITU MEASUREMENTS	1
2.1 Stress-Strain Measurements	1
2.2 Dip Closure and Stress Profiles	7
3 DISCUSSION	7
4 CONCLUSIONS	11
5 ACKNOWLEDGEMENT	11
6 REFERENCE	11
APPENDIX I SUPPLEMENTARY GRAPHS	12

LIST OF FIGURES

1.	Location plan of 68-52 stope	2
2.	Location of measuring stations in panel P3	3
3.	Stress-strain behaviour of backfill placed at station P3-1	4
4.	Stress-strain behaviour of backfill placed at station P3-2	4
5.	Stress-strain behaviour of backfill placed at station P3-3	5
6.	Vertical stress-strain behaviour of backfill placed at stations P3-1, 2 and 3 - with closure correction and adjustment for shrinkage	6
7.	Increase in vertical stress with respect to distance to face at stations P3-1, 2 and 3	6
8.	Distribution of closure across backfill panel - dip section	8
9.	Distribution of vertical backfill stress across backfill rib - dip section	9

1 INTRODUCTION

This report documents the measurements which were undertaken, between November 1988 and June 1989, to determine the in situ behaviour of classified tailings backfill and of the surrounding rockmass in panel P3 of the 68-52 backfill stope at Vaal Reefs 5 Shaft. Two types of backfill behaviour were of particular interest, namely confined compression behaviour and complete rib behaviour. The 68-52 stope is at an approximate average depth below surface of 2030 m and the reef dips towards the northwest at about 10°. The layout of the panels in the 68-52 stope is indicated in Figure 1. Due to the occurrence of numerous geological features (faults and dykes) a scattered mining method is used on this mine.

2 IN SITU MEASUREMENTS

Three measuring stations, each comprising three COMRO hydraulic stress meters orientated to measure in the vertical, strike and dip directions, together with a COMRO mechanical closure meter (for closure and strain determination) were installed 5 m from the face inside a backfill paddock in panel P3 on 17 November 1988. In order to also measure closure outside the backfill, a closure and ride station was installed down dip of the paddock near the P3 gully edge. The locations of these stations are indicated in Figure 2. After installation a winch cubby was created which left the first 1 m on the face side of the paddock unconfined.

2.1 Stress-Strain Measurements

The stress-strain behaviour of the backfill measured at station P3-1, installed 1,5 m up from the bottom edge of the paddock and in a stope width of 1,215 m, is shown in Figure 3. The maximum vertical and strike stresses are 2,4 MPa and 0,45 MPa respectively at about 14,5 per cent strain. The vertical nature of the last portion of the vertical stress curve implies that the closure meter had stopped working after 14 per cent strain (i.e. 170 mm of closure) and therefore the maximum stresses recorded probably occurred at slightly higher strains than those indicated. After a dip stress of 0,17 MPa was reached at 12 per cent strain the dip stress meter failed.

Shrinkage of the backfill material causes an air gap to form between the top of the backfill and the hangingwall and, therefore, allows some closure to occur without generating any stresses in the backfill. The amount of shrinkage that has occurred is, therefore, equivalent to the strain value at which stresses begin to be generated and can be estimated from a stress-strain graph. Figure 3 indicates that shrinkage at this station was about seven per cent.

The stress-strain behaviour of the backfill measured at station P3-2, installed 3 m up from the bottom edge of the paddock and in a stope width of 1,180 m, is shown in Figure 4. The maximum vertical, strike and dip stresses are 3,8 MPa, 1,6 MPa and 1,3 MPa respectively at about 10 per cent strain.

The vertical portion of the curves suggests that the closure meter at this station malfunctioned at 10 per cent strain (i.e. 120 mm of closure) and that the actual strains associated with the maximum stresses are much higher. Figure 4 indicates that shrinkage at this station was about four per cent.

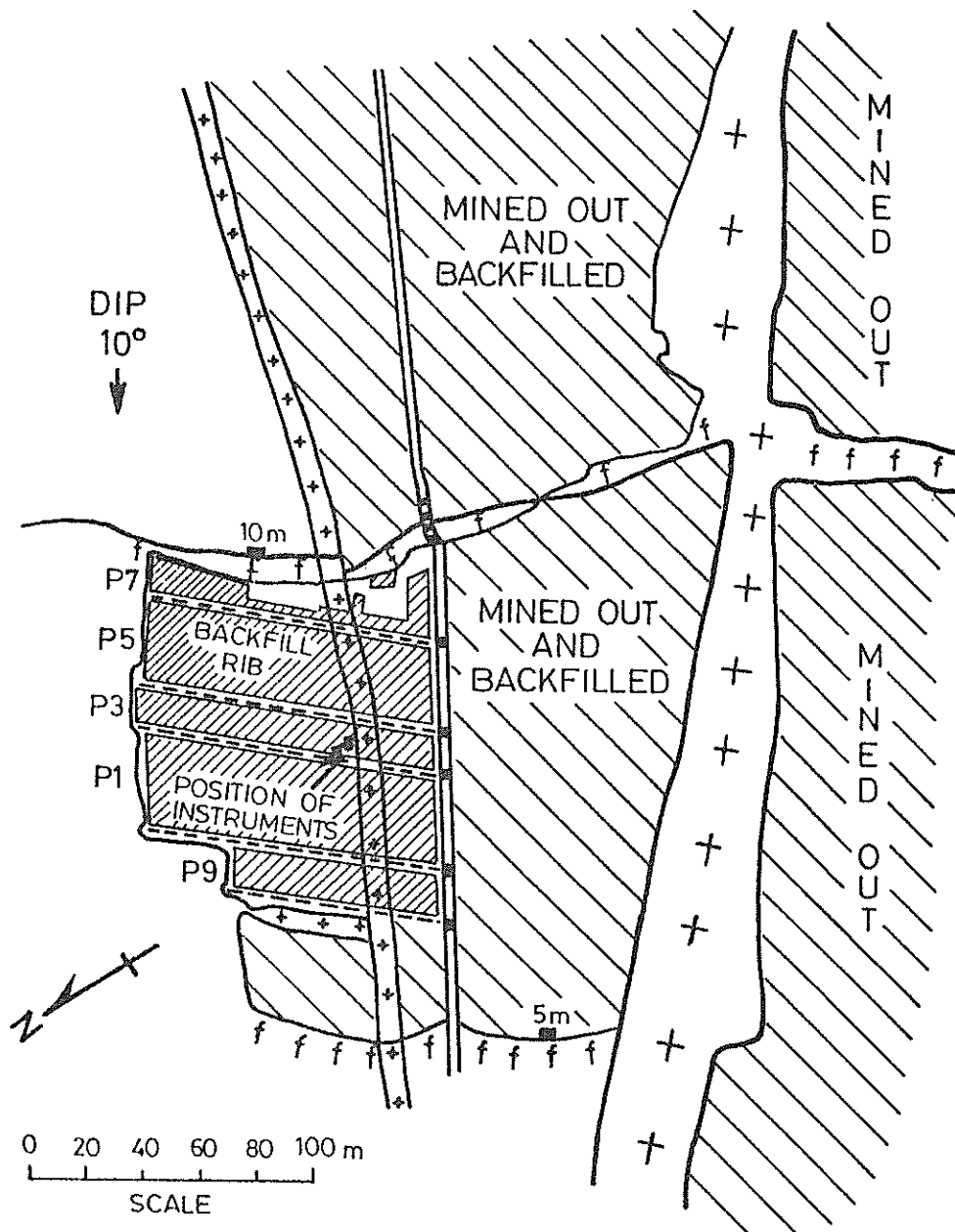


Figure 1 LOCATION PLAN OF 68-52 STOPE

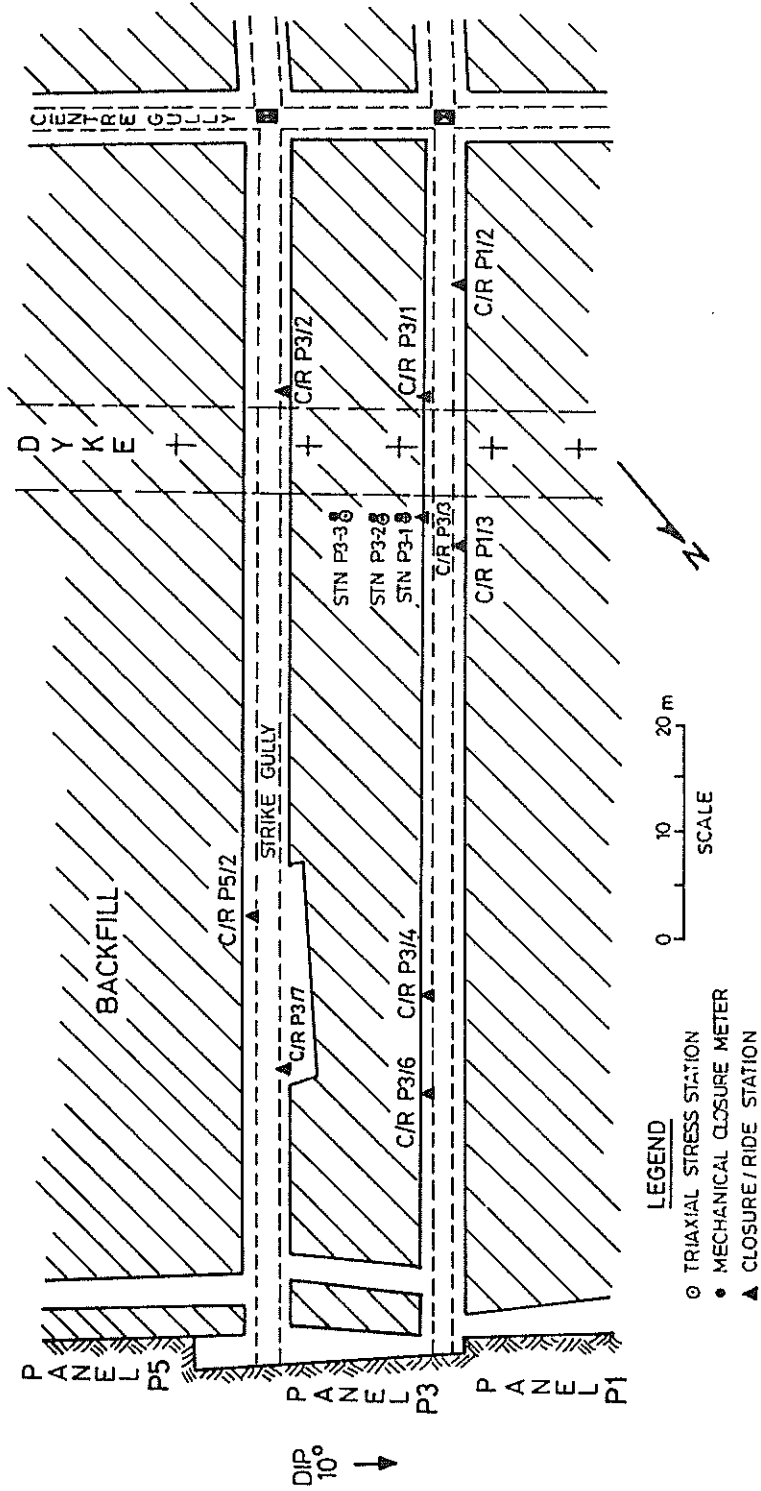


Figure 2 LOCATION OF MEASURING STATIONS IN PANEL P3

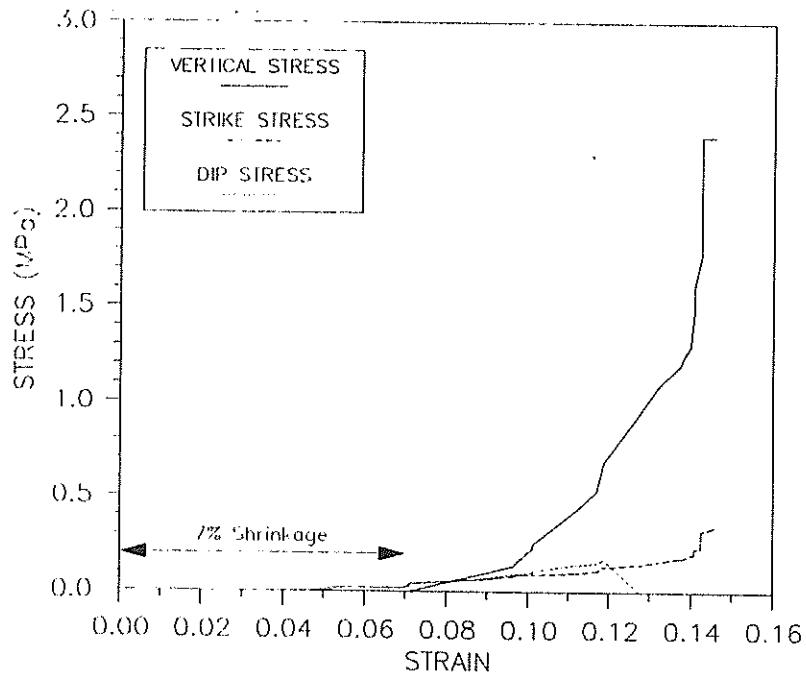


Figure 3 STRESS-STRAIN BEHAVIOUR OF BACKFILL PLACED AT STATION P3-1

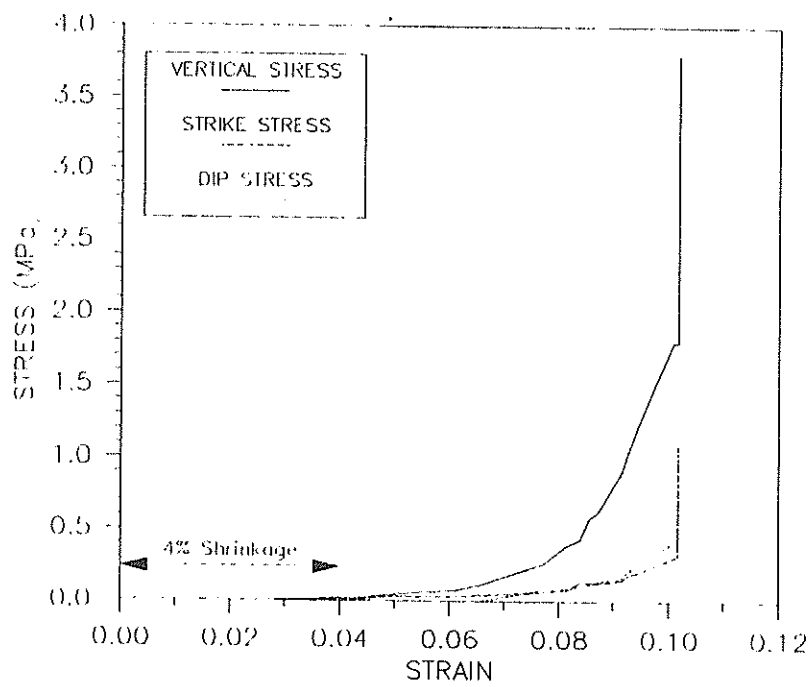


Figure 4 STRESS-STRAIN BEHAVIOUR OF BACKFILL PLACED AT STATION P3-2

The stress-strain behaviour of the backfill measured at station P3-3, installed 7 m up from the bottom edge of the paddock and in a stope width of 1,045 m, is shown in Figure 5. The maximum vertical, strike and dip stresses are 4,0 MPa, 1,6 MPa and 1,7 MPa respectively at about 13 per cent strain. The closure meter apparently ceased to work after about 12,5 per cent strain (i.e 130 mm of closure) and once again the maximum strains are probably much higher than those indicated. Figure 5 indicates that shrinkage at this station was about six per cent.

It can be assumed (Gürtunca *et al.*, 1989) that after 2-3 MPa backfill stress the closure rate inside the backfill is similar to that measured outside the backfill. It is, therefore, possible to adjust the internal closures by the same amount of increase recorded outside the paddock and recalculate the internal strains. Vertical stress-strain curves, which use these corrected strains and which have been individually adjusted to compensate for shrinkage, are presented in Figure 6 for comparison with each other and with the laboratory determined confined compression curve for backfill with a 43 per cent porosity.

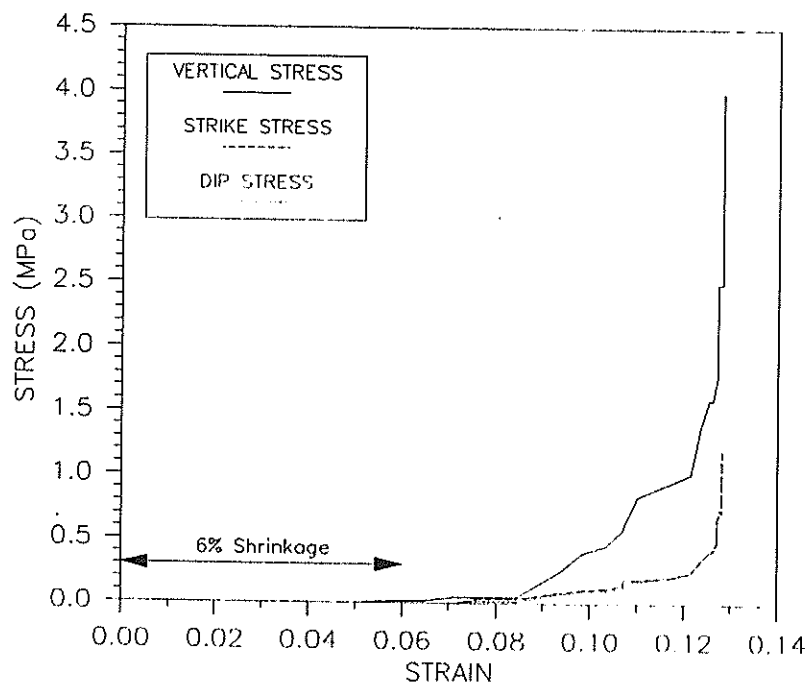


Figure 5 STRESS-STRAIN BEHAVIOUR OF BACKFILL PLACED AT STATION P3-3

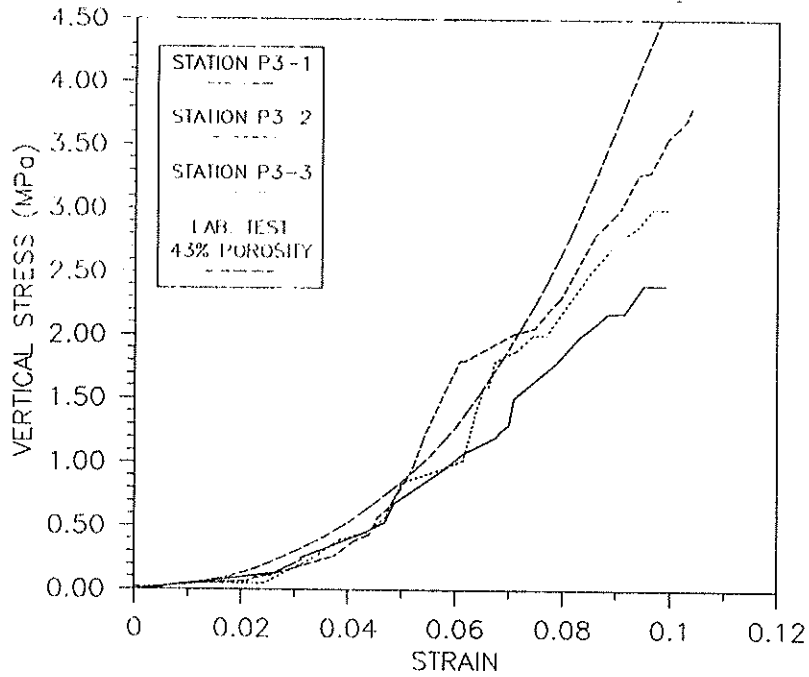


Figure 6 VERTICAL STRESS-STRAIN BEHAVIOUR OF BACKFILL PLACED AT STATIONS P3-1, 2 AND 3 - WITH CLOSURE CORRECTION AND ADJUSTMENT FOR SHRINKAGE

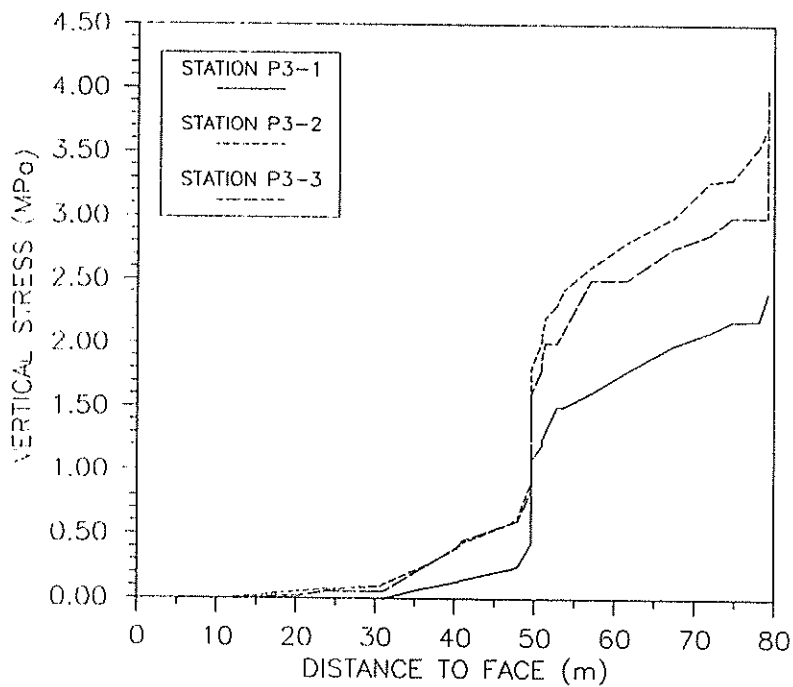


Figure 7 INCREASE IN VERTICAL STRESS WITH RESPECT TO DISTANCE TO FACE AT STATIONS P3-1, 2 AND 3

Another aspect of the in situ behaviour is the relationship between stress build up and distance to face or face advance. The increase in vertical stress with respect to distance to the face for all three stations is shown in Figure 7. The maximum vertical stresses (i.e. 2,4 MPa at station P3-1, 3,8 MPa at station P3-2 and 4,0 MPa at station P3-3) were measured when the distance to the face was about 79 m, which corresponds to a face advance of 74 m. The face stood idle for a period of time when it was at a distance of about 50 m and when it had reached the mining limit at 79 m. The individual graphs of stress versus distance to the face for each station are presented in Appendix I.

2.2 Dip Closure and Stress Profiles

In Figure 8 the results obtained from closure and ride station P3/3 (outside the backfill) and the mechanical closure meters (inside the backfill) are plotted together. This figure, therefore, depicts the closure profile on dip across the panel at different distances to the face and serves to highlight the relation between closure inside backfill and closure outside backfill. The uppermost curve shows the measurements taken when the face was 10,6 m from the measuring stations. The lowest curve shows the maximum closure recorded at each station, i.e. when the face had reached a position 79,2 m away. In the figure the corresponding vertical backfill stresses at each station are given in brackets. The bunching of the curves for stations P3-2 and P3-3 implies that the closure meters at these stations malfunctioned after experiencing 120-130 mm of closure. These closure results are also presented in Appendix I, Figure I.4, in the form of closure versus distance to face.

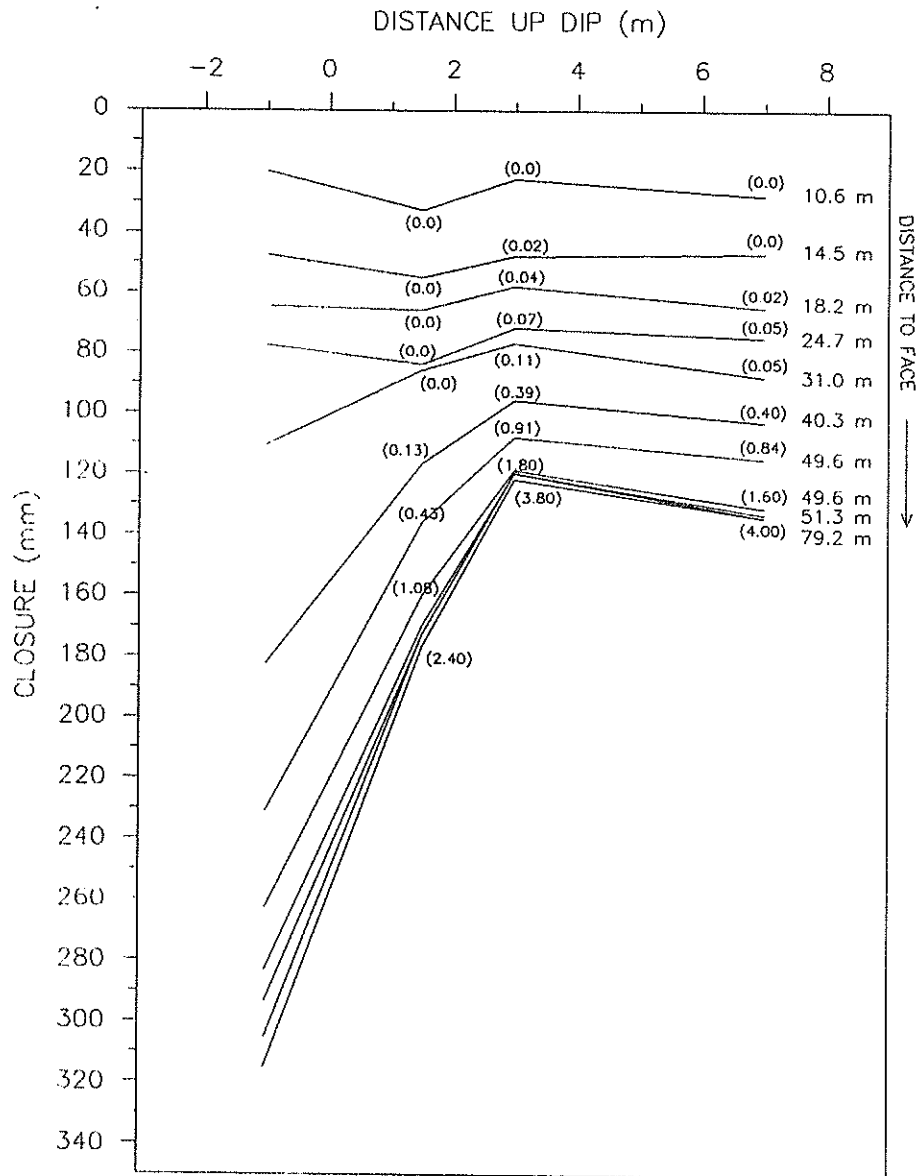
Figure 9 shows the vertical stress profile on dip through the backfill rib for various common strain values (given in brackets). The strains are determined on the same basis as those used in Figure 6, i.e. calculated from corrected closures and adjusted for shrinkage.

3 DISCUSSION

Stress-strain behaviour

The in situ stress-strain behaviour of the classified tailings backfill placed in the 68-52 stope, panel P3, has been determined successfully at the three measuring stations within the backfill rib.

The low levels of backfill stresses which were recorded are almost certainly due to the considerable amount (four to seven per cent) of shrinkage which was indicated in the stress-strain graphs (cf. Figures 3,4 and 5). If shrinkage had been eliminated then these stress levels might have been reached within distances of 40 to 50 m of the face. Stresses should be generated in backfill within a very short time after placement, but the effect of shrinkage is



Figures in brackets indicate vertical stress (MPa)

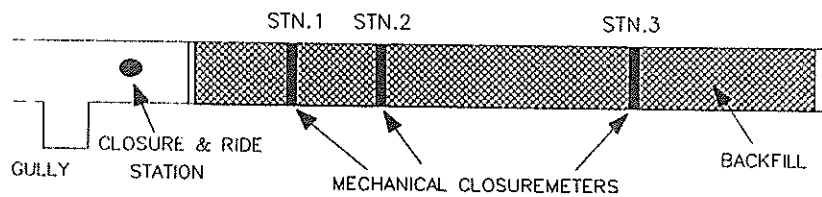


Figure 8 DISTRIBUTION OF CLOSURE ACROSS BACKFILL PANEL - DIP SECTION

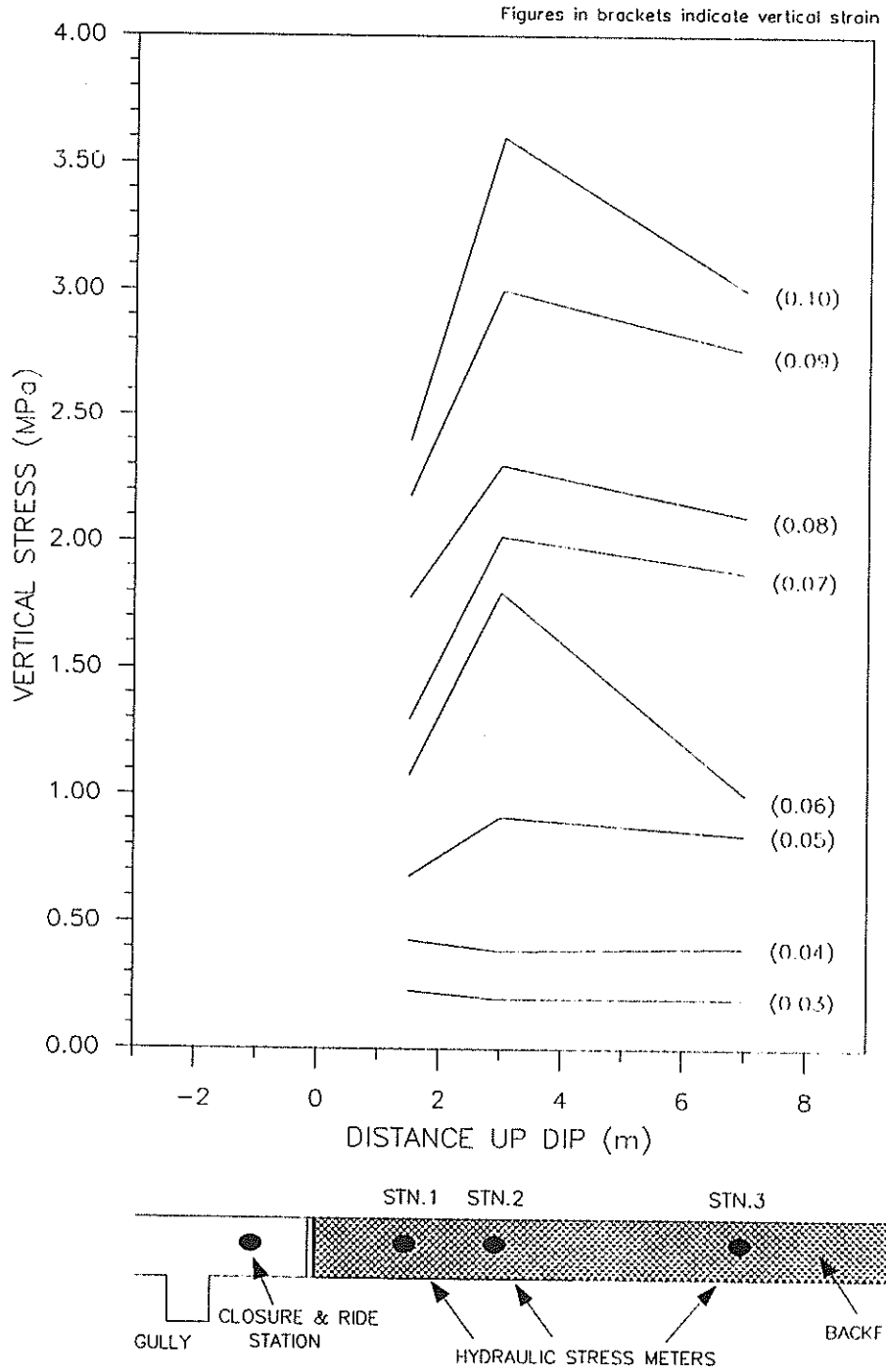


Figure 9 DISTRIBUTION OF VERTICAL BACKFILL STRESS ACROSS BACKFILL RIB - DIP SECTION

to delay the generation of backfill stresses and, therefore, support loads by several days. In this particular instance the face was advanced about 10 m (i.e. distance to face was 15 m) before any stresses were recorded (cf. Figure 7). This is equivalent to placing the backfill at 15 m from the face, as opposed to an actual distance of 5 m or 6 m, and results in the backfill providing little or no support resistance in the face area. This is obviously unacceptable in terms of face area support and the control of rockfalls.

The vertical sections of the curves in Figure 7 at face distances of about 50 m and 79 m indicate that stresses continue to build up in the backfill even when the face is not being advanced. This is partially attributable to the mining of adjacent faces and partially as a result of time dependent closure.

Confined compression behaviour

Confined compression behaviour is a particular type of stress-strain behaviour which usually occurs in the centre of a paddock, i.e. where the maximum confinement is likely to occur (Gürtunca *et al.*, 1989).

Figure 6 shows that there is quite good agreement between the in situ stress-strain curve for station P3-2 and the laboratory determined confined compression curve for backfill with a porosity of 43 per cent. The slight deviation of the P3-2 in situ curve from the 43 per cent laboratory curve can be attributed to an actual average in situ porosity of 44 per cent (determined from underground backfill sampling). The larger deviation of the P3-3 in situ curve from the 43 per cent laboratory curve may also be due to the difference in porosity but, as will be seen in the next section, it is more likely due to low confinement. In the case of station P3-1 there is almost certainly a lack of confinement due to the station's proximity to the paddock edge and, therefore, the behaviour at this station can not be considered to be that of confined compression.

Complete backfill rib behaviour

Figure 8 shows that the closure measured inside the backfill is about 40 per cent less than that measured at the closure and ride station outside the backfill. This is similar to findings at other mines. The figure also indicates that bending of the hangingwall and footwall (i.e. differential rates of closure inside and outside the backfill) occurs after about 0,4 MPa vertical stress is measured in the backfill. Previous work (Gürtunca *et al.*, 1989) has shown that the rates of closure inside and outside the backfill become equal again after about 3 MPa vertical stress in the backfill. Although it is not immediately clear from Figure 8, due to the malfunctioning of closure meters, the indication is that at the site under discussion this is occurring at about 2 MPa.

The curves in Figure 9 show that at low strains (up to four per cent) the vertical stresses are similar at all stations, but at larger strains (i.e. five per cent and greater) higher stresses are generated at station P3-2 than at the other two stations. This can be attributed to the smaller amount of shrinkage and the higher degree of confinement that existed at station P3-2. Although station P3-3 was located well inside the backfill rib the stoping width up dip from it was approximately 2 m and it is possible that there was a large gap between the backfill and the hangingwall in this upper zone. This could have prevented the necessary confinement being generated up dip of station P3-3 and produced a similar affect to being near the edge of the backfill paddock. Station P3-1 was located close to the paddock edge and winch cubby in an area of possible dilation and this accounts for the lower stresses recorded at this station.

4 CONCLUSIONS

- (i) The in situ stress-strain behaviour of the classified tailings placed in the 68-52 stope, panel P3, has been established at three positions inside a backfill paddock.
- (ii) The backfill at station P3-2 is under a state of confined compression which is comparable to that observed in laboratory tests. Any discrepancy is due to the difference between the in situ porosity of 44 per cent and the laboratory test porosity of 43 per cent.
- (iii) Shrinkage at the three stations was found to be high (four to seven per cent) and this resulted in low backfill stresses and, therefore, low support loads being generated even after 74 m of face advance; this has the effect of reducing the face support benefits that can be derived from backfill.
- (iv) The complete backfill rib behaviour observed at this site is similar to, and confirms, behaviour observed at other mines (Gürtunca *et al.*, 1989).

5 ACKNOWLEDGEMENT

The co-operation of the Management and Staff of Vaal Reefs Exploration and Mining Co., Ltd. and their permission to publish these results is gratefully acknowledged.

6 REFERENCE

GÜRTUNCA, R.G., JAGER, A.J., ADAMS, D.J. and GONLAG, M.D., 1989. The in situ behaviour of backfill materials and the surrounding rockmass in South African gold mines. 4th International Symposium on Mining with Backfill, Montreal, October.

APPENDIX I

SUPPLEMENTARY GRAPHS

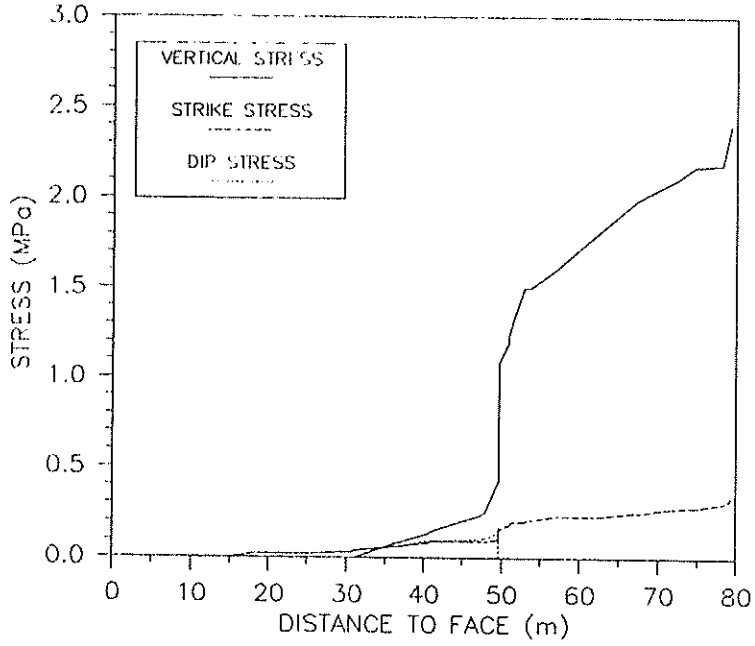


Figure I.1 INCREASE IN STRESSES WITH RESPECT TO DISTANCE TO FACE AT STATION P3-1

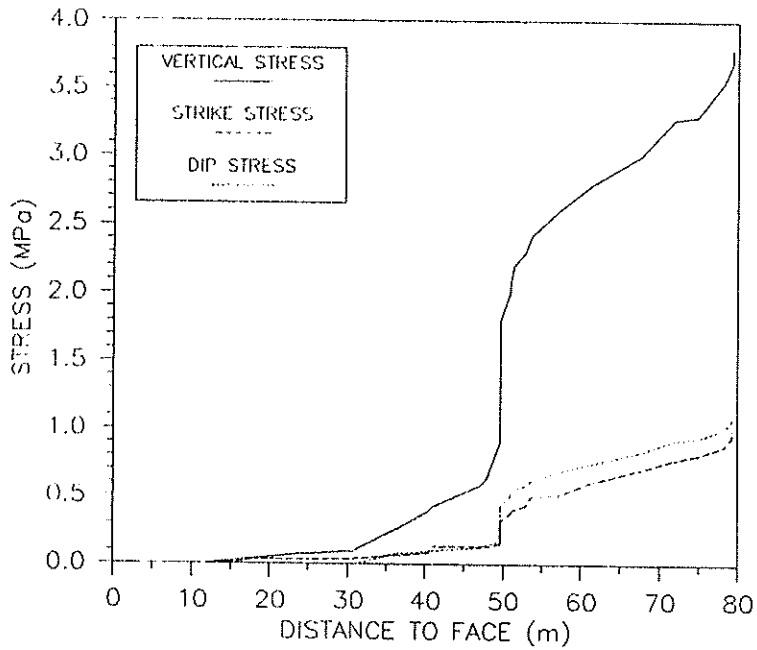


Figure I.2 INCREASE IN STRESSES WITH RESPECT TO DISTANCE TO FACE AT STATION P3-2

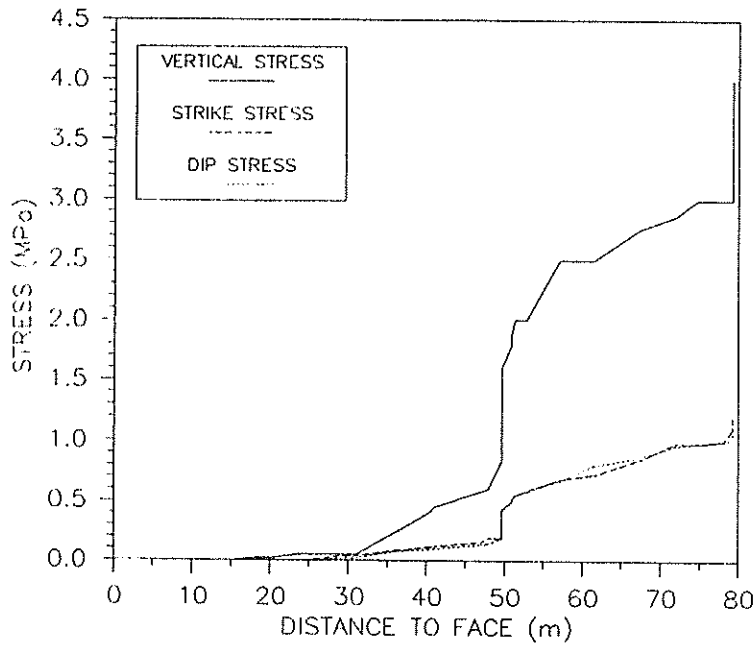


Figure 1.3 INCREASE IN STRESSES WITH RESPECT TO DISTANCE TO FACE AT STATION P3-3

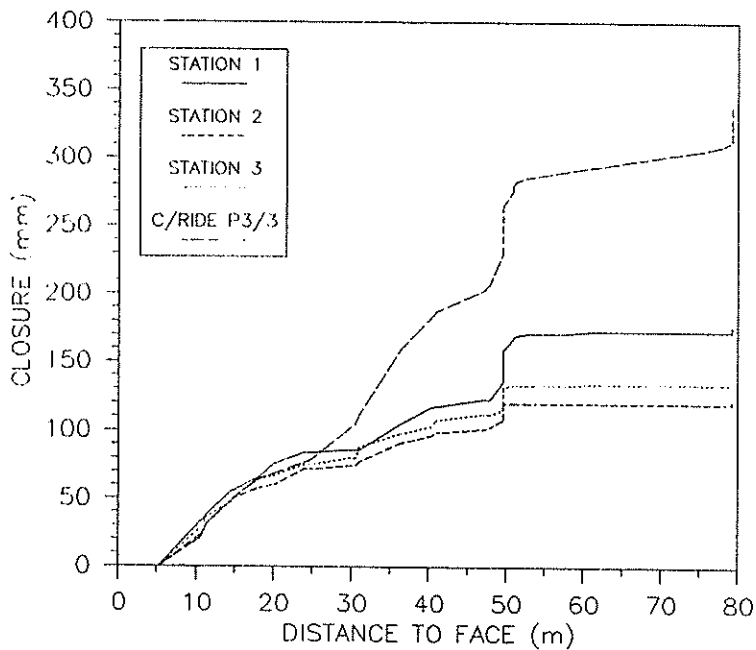


Figure 1.4 RELATIONSHIP BETWEEN CLOSURE AND DISTANCE TO FACE MEASURED AT CLOSURE STATIONS LOCATED INSIDE AND OUTSIDE THE BACKFILL

