EXPLOSION RESISTANT UNDERGROUND STOPPINGS

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INTRODUCTION

It is, amongst other countries, a requirement in the USA, South Africa and Australia for any abandoned panel to be sealed for the prevention of Coal Dust Explosions in Underground Coal Mines.

The objective of this paper is to ensure the most cost effective and durable means of sealing.

Stoppings for containment must be capable of withstanding 140 kPa (14 metres water) static pressure. This type of seal is the minimum requirement for sealing any panel or other mined out area.

Explosion-proof stoppings or seals must be capable of withstanding 400 kPa (40 meters water) static pressure and are required when an area remains in the explosive range.

Design Requirement

With the specified load on a rectangular stopping, a wall can be designed by any civil engineer in accordance with approved design codes. These codes have a built in safety factor of 3. Any civil engineer is legally bound to design in accordance with the codes.

The more appropriate route to follow in this instance would be the empirical testing of walls. This will result in a safety factor of just more than 1.

It must be noted that empirical tests for this application are an accepted approach internationally and were undertaken by the "United States Department of Interior" where the 140 kPa requirement originated.

EXISTING TECHNOLOGY

The United States Department of the Interior undertook empirical explosion tests on various construction methods and materials.

A report 9382 issued by their U.S. Bureau of Mines deals with the following construction methods:

- Solid concrete block seals
- Cementitious foam seals

A further report 9634 deals with.

- Polymer construction materials.

The wall thickness/seam height ratio as proposed in the above reports was used as a guide for the South African conditions.

This report summarises the findings and cost implications (1999 money) of the above three methods and also deals with construction methods as developed in South Africa for a typical 4m seam height, 7m wide.

CONSTRUCTION METHODS AS TESTED IN THE USA

It should be noted that the US designs are only proven up to a max height of 2.1m for the 140 kPa requirement.

Solid Concrete Blocks

This method is based on the gravity block wall system. The explosion test was successfully conducted on a wall with the following parameters:

Concrete block sizes:	205 x 205 x 411 mm
Mass of block	35 kg
Wall size:	2.1 high x 6.1m wide
Maximum thickness:	822 mm
Mortar between bricks:	Yes
Keying:	150 x 150 mm angle iron bolted on floor and sides

South African conditions for a 4m-seam height
Wall thickness/seam height ratio = 0,4
Wall thickness for a 4m seam height = 1600mm
Volume of 7m wide seals = 45m^3

Estimate for solid concrete blocks

45m^3 @ R867	$6 500
Bolt and angle iron key	$1 666
Total	$8 166

Estimate for mass concrete stopping
Prices inclusive of transportation, shuttering and placing will range between $183 and $266 per m^3 i.e. between $8 250 and $12 000 per stopping.

Cementitious Foam Seals (CFS)

The material can generally be defined as lightweight cement with no stone or coarse aggregate.

The explosion test was successfully conducted on a wall with the following parameters:

Wall size:	2.1 high x 6.1m wide
Thickness:	1.3m
Material compressive strength:	1.38MPa (200PSI)

South African conditions for a 4m-seam height
Wall thickness / seam height ratio = 0.62
Wall thickness for a 4m seam height = 2.480m
Volume for a 7m wide seal = 70m^3

Estimate for foam seal stopping
Fosroc fabricates this product.

CFS with a maximum crushing strength of 0.75 MPa is presently being placed underground. CFS with a crushing strength of 1.4MPa will cost in the order of \$113/m^3.

A stopping of 70m^3 will therefore cost in the order of \$7 833.

A local company "Swift" is presently investigating a more economic CFS product. This product is presently in use in Australia.

Polymer Construction Materials

This is a technique of filling the complete stopping with broken stone and then inserting the Polymer product to fill the voids. The thickness of the plug required and costs will be similar to paragraph 3.1 above i.e. \$8 000.

CONSTRUCTION METHOD AS DEVELOPMENTS IN SOUTH AFRICA

Reinforced Concrete Wall

This wall was designed from basic principles and does not require any empirical testing.

The anchoring of this wall into the floor, roof and sides will determine the long-term integrity of this design in accordance with Annexure A.

Proposed Design
Concrete strength = 25 MPa
Wall thickness = 500mm
Main reinforcement = y 32 @ 200 (vertically)
Distribution reinforcement = y16 @ 200 (horizontally)
Bolt anchoring = 20 No bolts in the floor and roof
Or
Key anchoring = 500mm slot in floor and roof
Estimate for stopping
This wall will cost in the order of \$8 400.

Space frame / Gunite Wall

This wall was developed with empirical testing at Koornfontein mines in South Africa. It involves the installation of a first space frame with Poly Propylene backing and then multiple space frames to obtain the required thickness.

Conventional reinforcing is then installed and covered up with guniting in accordance with the attached Method Statement.

Estimate for stopping
This wall cost in the order of \$2 500.

Construction from Surface

Abandoned workings may in some cases be too costly or dangerous to re-equip to allow workmen to install a stopping underground.

Construction from surface may therefore be a requirement.

Plugs from surface were previously successfully installed in South Africa to contain water.

Further development of this system with local contractors is presently in hand.

RECOMMENDATION

The closure of abandoned workings in accordance with the proposed legislation could result in unforeseen costs for the Mining Industry.

In order to reduce this expenditure, the following two actions are recommended: -

- The number of entries into a section must be minimised.
- The height of these entries must be kept to a minimum to reduce the thickness of the plugs.

At present the most cost-effective option appears to be the space frame / gunite wall.

Attachment

Method Statement
for
Explosion Resistant
Underground Containment Stoppings
Using the
Space Frame / Gunite Wall

Date: June 1999

Compiled by: C Strydom

CONTENTS

1. *INTRODUCTION*

Various types of stoppings, as used internationally and locally, were investigated and costs to determine the most cost effective and durable stopping.

2. *LEGISLATED REQUIREMENT*

Any abandoned underground panel must be sealed in accordance with legislation for the prevention Coal Dust Explosions in Underground Mines. The requirement calls for:

- 140 kPa Containment stoppings (minimum sealing requirement)
- 400 kPa Explosion stoppings (when sealed area remains in the explosive range)

3. *METHOD STATEMENT FOR SPACE FRAME / GUNITE STOPPING / REINFORCEMENT*

The system was developed after 7 empirical tests were undertaken in order to refine the method statement. Final test for containment stoppings i.e. 140kPa was concluded in May 1999 to the approval of the "Department of Mineral and Energy Affairs.

This system involves the use of conventional space frames, gunite and reinforcement for any size underground haulage in accordance with the following sequence of events:

- Select Wall type A to E from Annexure A
- Install 16mm Dia Roof Bolts @ 250mm centres on all four contact zones
- Clean all four contract zones of dust and loose material
- Install 50mm space frame or similar approved with Poly Propylene backing
- Install monitor tube and drain pipe in 1 of panel stoppings
- Install further 50mm space frames up to the required thickness as per Annexure B
- Install main reinforcement as per Annexure B
- Gunite cover over the reinforcement as per Annexure B

4. *MATERIALS*

Gunite

Design mix to ensure a cube crushing strength of 30 Mpa at 28 days.

Roof Bolts

Full column resin anchored standard rock bolts 1 metre long. 16mm dia in 22mm hole.

Monitor Tube

12mm dia gas sampling tube with valve near the top of the stopping.

Drain Pipe

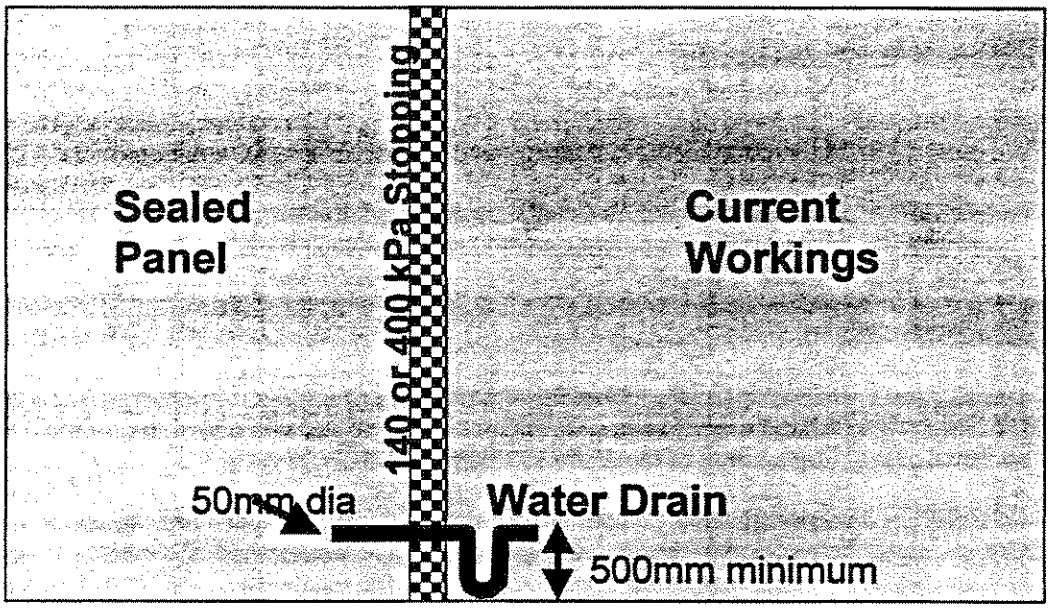
50mm dia water relief (with 500mm U tube for gas control) near the floor of the stopping.

Space Frame

Square mesh welded in 50 x 50 mm cubes using 1.6 mm high tensile welded mesh or any equivalent product to prevent sluffing of gunite.

Reinforcement

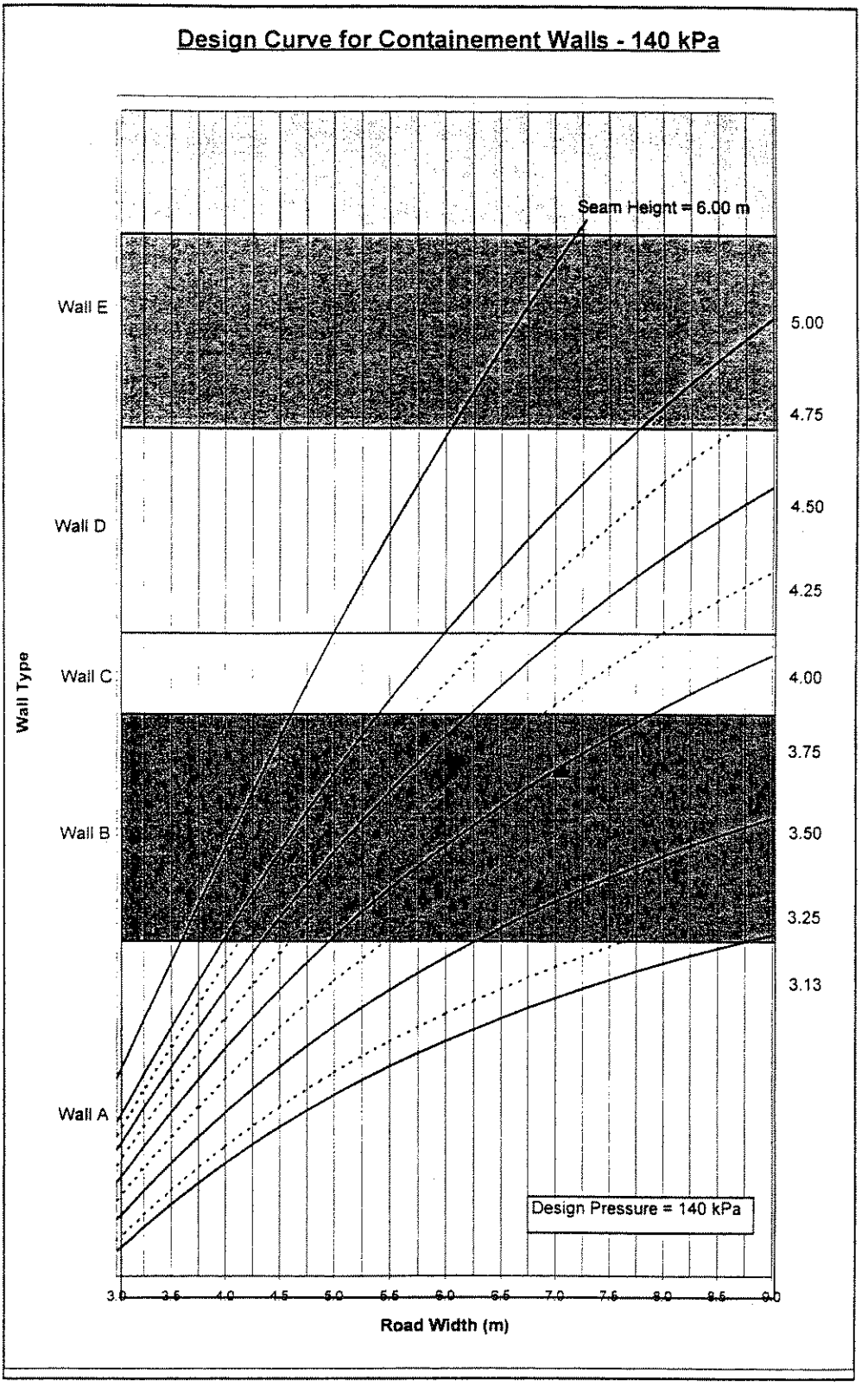
High tensile deformed reinforcement at 150mm centres vertically and horizontally. Any horizontal lap length must be at least 60 x reinforcement diameter. No vertical lap length of reinforcement to be accepted.


Sealed
Panel
140 or 400 kPa Stopping
Current
Workings
50mm dia
Water Drain
500mm minimum

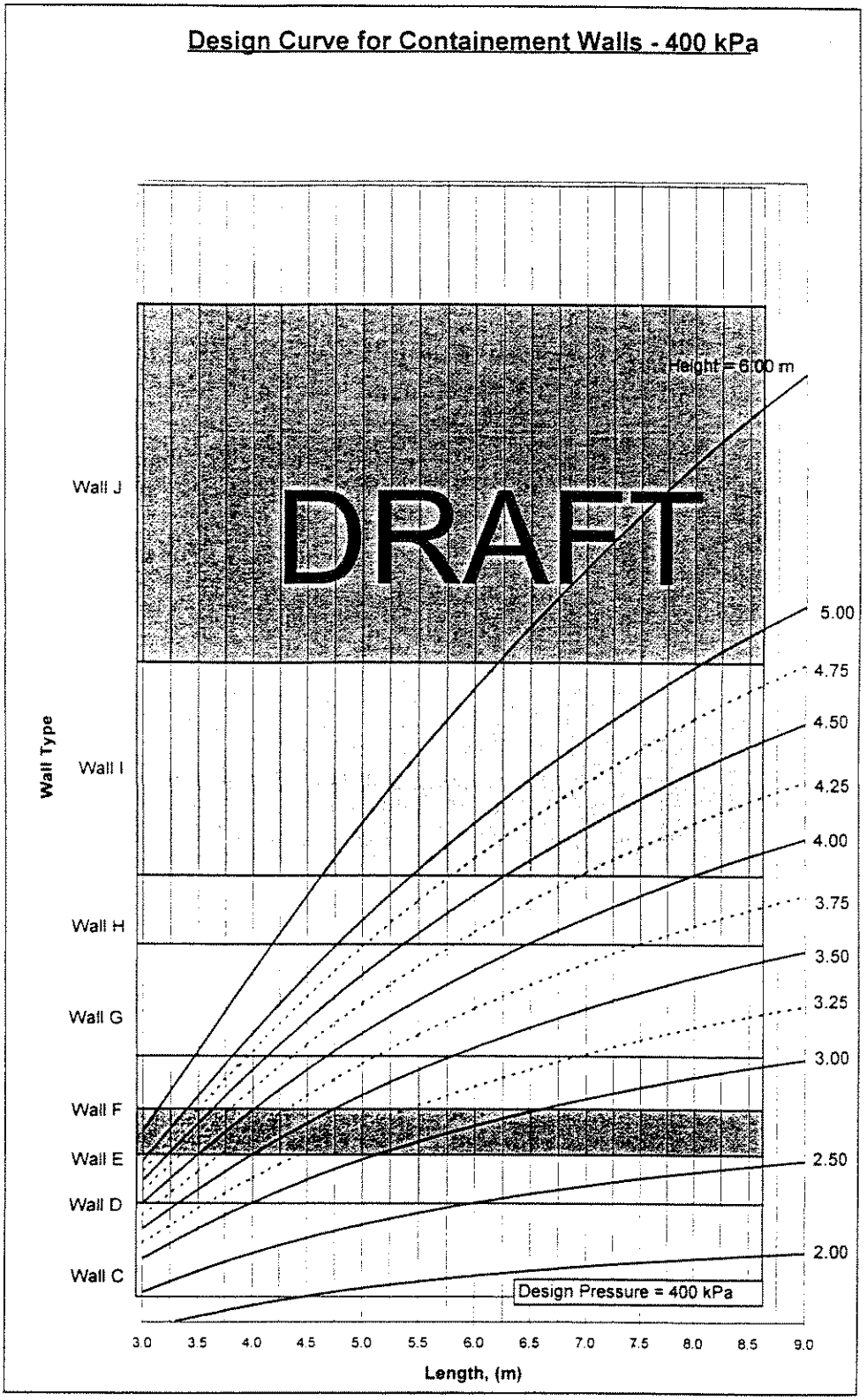
Containment Wall Design Curves:

ANNEXURE A

Example
Road width 7m] Answer is Wall B as shown below ▲
Seam Height 4m]



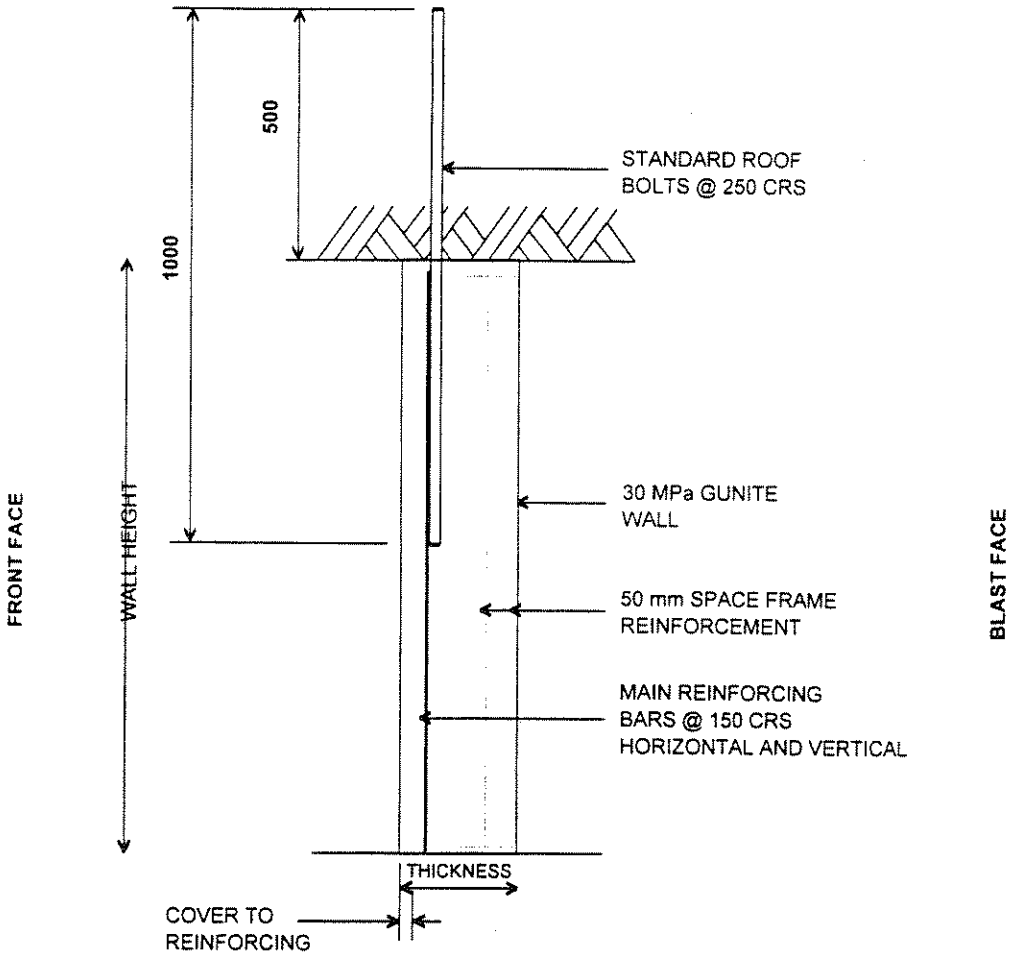
ANNEXURE B


Design Curve for Containement Walls - 400 kPa
DRAFT
Height = 6.00 m
Wall J
Wall I
Wall H
Wall G
Wall F
Wall E
Wall D
Wall C
Wall Type
5.00
4.75
4.50
4.25
4.00
3.75
3.50
3.25
3.00
2.50
2.00
Design Pressure = 400 kPa
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
Length, (m)

ANNEXURE C

Wall Definitions:

Wall	Thickness	Reinforcing	No. of Space Frame Reinforcement	Cover (mm)
A	140	Y12's @ 150	2	16
B	160	Y16's @ 150	2	24
C	160	Y20's @ 150	2	20
D	190	Y12's @ 150	3	16
E	200	Y16's @ 150	3	18
F	210	Y20's @ 150	3	20
G	250	Y16's @ 150	4	18
H	260	Y20's @ 150	4	20
I	310	Y20's @ 150	5	20
J	350	Y32's @ 150	5	36



SECTION THROUGH WALL