Assessment of the performance of Composite Liner: Shotcrete & TSL

Moderators:

Profs. N. Fowkes, D. Mason, C.M. Khalique, G. Hocking

Student Members:

Z. Dlamini, T. Motsepa, S.O. Ojako, A. Nour, V. Magagula

Mathematics In Industry Study Group - 2016

11^{th} - 15^{th} January 2016

PRESENTATION OUTLINE

1. Background Information
2. Motivation and Aim of the Study
3. Investigations
4. Tunnel Model

Background Information

Shotcrete

- Shotcrete is used to provide structural tunnel support.
- It is structurally strong, but **expensive** to apply. (100 mm thick)

Thin Spray on Liners (TSL)

- TSL's are thin spray on liners (4mm) that reduce rockburst.
- TSL's are **inexpensive** to apply but don't provide structural support.

AIM

The aim is to investigate if **TSL's** can be used in combination with **Shotcrete** to improve structural performance.

QUESTIONS

- Is it possible to reduce the shotcrete thickness?
- Can this reduction be achieved by the TSL application over or under shotcrete?
- Shotcrete performance should remain the same.

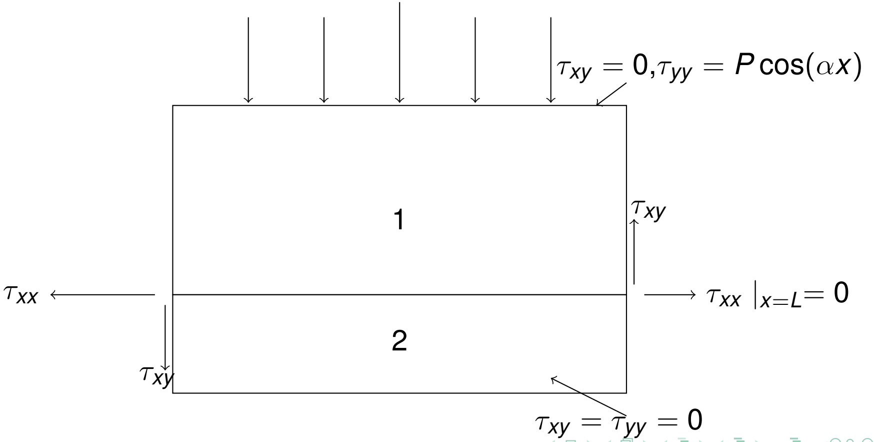
INVESTIGATIONS

- **Plane Stress Elasticity Model**
- **Tunnel Model**

Plane Stress Elasticity Model

We have Airy Stress function $\phi(x, y)$ with

$$\nabla^4 \phi_i = 0, \quad \text{in each region } i = 1, 2.$$



Plane Stress Elasticity Model

Airy Stress function $\phi(x, y)$:

$$\sigma_x = \frac{\partial^2 \phi}{\partial y^2}, \quad \sigma_y = \frac{\partial^2 \phi}{\partial x^2}, \quad \tau_{xy} = -\frac{\partial^2 \phi}{\partial x \partial y}.$$

Compatible condition

$$\nabla^4 \phi^{(i)} = 0, \quad i = 1, 2$$

Look for solutions of the form

$$\phi^{(i)} = \cos(\alpha x) f^i(y), \qquad \alpha = \frac{\pi}{2L}$$

$f(y)$ satisfies the ODE

$$\alpha^4 f - 2\alpha^2 f'' + f'''' = 0.$$

Upon solving we get

$$f^i(y) = C_1^i \cosh(\alpha y) + C_2^i \sinh(\alpha y) + C_3^i y \cosh(\alpha y) + C_4^i y \sinh(\alpha y), \quad i = 1, 2. \qquad (1)$$

Thus

$$\phi_i = \cos \alpha x \left(C_1^i \cosh \alpha y + C_2^i \sinh \alpha y + C_3^i y \cosh \alpha y + C_4^i y \sinh \alpha y \right).$$

8 constants to be determined by the boundary conditions

$$y = 0: \quad \tau_{yy}^1(x, 0) = -P \cos \alpha x, \qquad (2)$$

$$\tau_{xy}^1(x, 0) = 0 \qquad (3)$$

$$y = -w_1: \quad \tau_{yy}^1(x, -w_1) = \tau_{yy}^2 x, -w_1), \qquad (4)$$

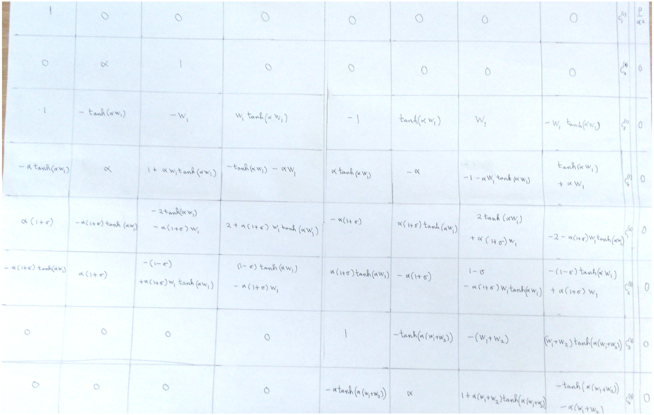
$$\tau_{xy}^1(x, -w_1) = \tau_{xy}^2(x, -w_1), \qquad (5)$$

$$u_x^1(x, -w_1) = u_x^2(x, -w_1) \qquad (6)$$

$$u_y^1(x, -w_1) = u_y^2(x, -w_1) \qquad (7)$$

$$y = -(w_1 + w_2): \quad \tau^2_{yy}(x, -(w_1 + w_2)) = 0 \tag{8}$$

$$\tau^2_{yx}(x, -(w_1 + w_2)) = 0 \tag{9}$$



1	0	0	0	0	0	0	0	$\zeta_1^{(1)}$	$\frac{p}{\alpha^2}$
0	α	1	0	0	0	0	0	$\zeta_2^{(1)}$	0
1	$-\tanh(\alpha w_1)$	$-w_1$	$w_1 \tanh(\alpha w_1)$	-1	$\tanh(\alpha w_1)$	w_1	$-w_1 \tanh(\alpha w_1)$	$\zeta_3^{(1)}$	0
$-\alpha \tanh(\alpha w_1)$	α	$1 + \alpha w_1 \tanh(\alpha w_1)$	$-\tanh(\alpha w_1) - \alpha w_1$	$\alpha \tanh(\alpha w_1)$	$-\alpha$	$-1 - \alpha w_1 \tanh(\alpha w_1)$	$\tanh(\alpha w_1) + \alpha w_1$	$\zeta_4^{(1)}$	0
$\alpha(1+\sigma)$	$-\alpha(1+\sigma)\tanh(\alpha w_1)$	$-2\tanh(\alpha w_1) - \alpha(1+\sigma) w_1$	$2 + \alpha(1+\sigma) w_1 \tanh(\alpha w_1)$	$-\alpha(1+\sigma)$	$\alpha(1+\sigma)\tanh(\alpha w_1)$	$2\tanh(\alpha w_1) + \alpha(1+\sigma) w_1$	$-2 - \alpha(1+\sigma) w_1 \tanh(\alpha w_1)$	$\zeta_1^{(2)}$	0
$-\alpha(1+\sigma)\tanh(\alpha w_1)$	$\alpha(1+\sigma)$	$-(1-\sigma) + \alpha(1+\sigma) w_1 \tanh(\alpha w_1)$	$(1-\sigma)\tanh(\alpha w_1) - \alpha(1+\sigma) w_1$	$\alpha(1+\sigma)\tanh(\alpha w_1)$	$-\alpha(1+\sigma)$	$1-\sigma - \alpha(1+\sigma) w_1 \tanh(\alpha w_1)$	$-(1-\sigma)\tanh(\alpha w_1) + \alpha(1+\sigma) w_1$	$\zeta_2^{(2)}$	0
0	0	0	0	1	$-\tanh(\alpha(w_1+w_2))$	$-(w_1+w_2)$	$(w_1+w_2)\tanh(\alpha(w_1+w_2))$	$\zeta_3^{(2)}$	0
0	0	0	0	$-\alpha \tanh(\alpha(w_1+w_2))$	α	$1 + \alpha(w_1+w_2)\tanh(\alpha(w_1+w_2))$	$-\tanh(\alpha(w_1+w_2)) - \alpha(w_1+w_2)$	$\zeta_4^{(2)}$	0

Conclusions

- TSL will be most effective if it penetrates fractures in the rock mass and repairs the fractures.
- In other circumstances we expect the TSL not to contribute.

We await confirmation from the analysis.

- Order of application of shotcrete and TSL

  If shotcrete is applied first it will bond strongly to the rough surface of the rock.

  If TSL is applied first the shotcrete will bond less strongly to the smooth surface of the TSL which may lead to debonding.


Thank you ...