Mix Design of Paste Fill for Underground Mining

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Underground Mining

Removal of ore deep underground
- Open stoping technique
- Waste material called tailings

Backfill
- To fill voids
- Dispose of mining wastes
- Two types: cemented & uncemeted

(Li 2014)
Paste Fill

- Type of cemented backfill
- Created from full mine tailings
  - Finer grain size distribution relative to other backfill types
  - Min. 15% of grains smaller than 20 μm
- Solid content in the order of 75-80%
The Problem

• Binder contributes approx. 8-15% of the total mining operation costs.
• Approx. 5% of all carbon dioxide emissions are represented by the cement industry.
Objective:

Determine a more economically and environmentally conscious mix design of paste fills, whilst maintaining strength and flow characteristic requirements.
Effective Paste Fill Mix Design

- Minimize the quantity of cement whilst meeting strength requirements.
- Maximise the amount of tailings disposed of whilst maintaining workability

Rheology vs Strength
Performance Parameters: Rheology

(Sivakugan et al. 2015)
Performance Parameters: Strength

- Strength developed from hydration of cement and water
- Quantified by unconfined compressive strength (UCS)
- Min. dependent on design requirements
  - Static stability
  - Dynamic stability
Methodology

Main aspects:

• George Fisher Mines (GFM) Tailings characteristics

• Mix Design
  • Paste fill strength characteristics
  • Paste fill flow characteristics
GFM Tailings Characteristics: Grain Size Distribution

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid Limit (LL)</td>
<td>22.0%</td>
</tr>
<tr>
<td>Plastic Limit (PL)</td>
<td>15.0%</td>
</tr>
<tr>
<td>Plastic Index (PI)</td>
<td>7.0%</td>
</tr>
<tr>
<td>Linear Shrinkage (LS)</td>
<td>2.5%</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>2.77</td>
</tr>
</tbody>
</table>
GFM Tailings Characteristics: Chemical Composition

![Graph showing chemical composition and distribution](image-url)
GFM Tailings Characteristics: Grain Shape
Mix Design

- **Binder types:**
  - 40% GPC & 60% Slag
  - 75% GPC & 25% Fly Ash
  - 100% GPC

- **Binder dosages:**
  - 3%, 5% & 7%

- **Polycarboxylate plasticizer:**
  - 0%, 4% & 6%

- **Curing periods:**
  - 7, 14, 28 and 56 days

27 Mixes
Strength Characteristics

- Unconfined compressive strength (UCS) tests
- Indirect tensile strength (ITS) test
UCS Tests Results

UCS Development in 100% Cement Paste Fill

UCS Development in Slag Blend Paste Fill

UCS Development in Fly Ash Blend Paste Fill
ITS Tests Results

ITS Development in 100% Cement Paste Fill

ITS Development in Slag Blend Paste Fill

ITS Development in Fly Ash Blend Paste Fill
E/UCS Relationship

E vs UCS for Paste Fill

- $E = 375 \text{ UCS}$
- $E = 210 \text{ UCS}$
- $E = 100 \text{ UCS}$

UCS (MPa) vs $E$ (MPa) graph with data points and trend lines.
UCS/ITS Relationship

ITS vs UCS for Paste Fill

- UCS = 10 kTFS
- UCS = 5 kTFS
- UCS = 2.5 kTFS

UCS (MPa)

ITS (kPa)
SEM Analysis of Paste Fill

7 Days

14 Days

28 Days
Flow Characteristics

Rheometer
  • Yield stress

Standardized Slump test
  • Slump ≈ 260mm
Flow Characteristics: Results

Yield Stress

Slump
Recommendations

Strength Characteristics of Paste Fill

◆ Increasing the range of binder and admixture dosage
◆ UCS and ITS testing of samples at 112 days
◆ Establish and refine the range of and E/UCS and UCS/ITS ratios

Paste Fill Rheology

◆ Determine yield stress measurements using the rheometer at set times
◆ Increase the range of binder and admixture dosage and number of yield stress tests on the same mix.
◆ Incorporate various types of plasticizer
Questions?