Design considerations for pillar systems in deep mines

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Content

- Role of pillars in mining
- Stope pillar loading approaches
- Pillar design
- Pillars in deep open-stoping mines
  - Widening of the panel
  - Increasing height of the panel
  - Failure of pillars
- Pillars in total extraction systems
- Conclusions
The role of pillars in mining

- Support pillars
  - local
  - regional
- Stabilising pillars
  - Rock burst control
- Protection pillars
  - Surface infrastructure (buildings, roads, …)
  - Mine infrastructure (shafts, service excavations, …)
Design considerations for pillar systems in deep mines

Individual stope pillars

Regional interpanel pillars

Mining methods in underground mining (2007)
Objective of pillar:
- Limiting shaft deformation
- Protecting mine infrastructure in vicinity of shaft
Stabilizing or control pillar system

- **Objective of stabilizing pillar:**
  - To minimize convergence in mined out area
  - To reduce rock burst hazard in deep mines

Diagram:
- Direction of mining
- Mined out stope (total extraction)
- Stope face
- Stope face
- Stope access
- Barrier pillar length up to 1km and more
- Barrier pillar
Design of pillars

- Choosing of accurate geometry and size to fulfill considered purpose
- Approach depends on purpose of pillar and geotechnical conditions
- Usual case: Strength of pillar > load of pillar
- Mining is a dynamic system → over time pillar loads may change significantly
Dead weight loading

- **Design principle**
  - Each pillar has to support the weight of rock strata allocated to it
  - Strength of pillar has to be greater than weight acting on it
  - Factor of safety is determined by importance of pillar workings
Displacement controlled pillar load

- Pillar load is determined by reaction of pillar to strata displacement as a result of mining

- Critical factors are:
  - Deformation properties of rock mass
  - Depth and extent of mining
  - Cross sectional area of pillar and pillar height

Salamon and Oravecz (1976)
Example of pillar loading in a deep mine

- Depth of mining: 900m
- Method of mining: Sublevel open stoping with paste fill
- Sequence of extraction
Influence of panel width

- Center pillar most highly stressed
- Increase in panel width $\rightarrow$ significant pillar stress increase
- $\rightarrow$ Widening of panel effects stress distribution negatively
Failure of pillars

- Complete pillar failure (no load bearing capacity anymore) → worst case scenario
- Significant stress increase near failed pillar
- Severity depends on number and position of failed pillar(s)
Effect of barrier pillars

- Pillar failure in one panel → no significant stress increase in other panels
- → Barrier pillar separates panels effectively and prohibits regional failure
- Critical is the barrier pillar width
Influence of panel height

- Post-Pillar mining situation
  - Depth 900m
  - 6 rooms; width 10m
  - Pillar width 10m
  - 32 slices; panel height 160m

- Increasing pillar height → significant pillar stress decrease
- Increasing height of panel effects stress distribution positively
- Change in abutment stress distribution
- Effect of pillar height on pillar strength
Total extraction systems

- **Aim:** extract ore-body as completely as possible
  - Longwall mining
  - Block Caving
  - Pillar retreat mining

- **Pillar load is determined by geometry of total extraction area**
  - Application of dead weight and displacement controlled loading model not possible
  - Very high stresses in the vicinity of abutments
  - Stress shadow below and above total extraction area

Galvin, Steijn and Wagner (1982)
Conclusions

- Pillars fulfill numerous and different purposes
- Design of a pillar depends on its purpose
- Design of deep mining pillars
  - Usually: Pillar strength > Pillar load
  - Open-stoping systems → Displacement controlled loading of pillars
    - Pillar load governed by layout of panel
    - Widening of a panel → increase of pillar stresses (disadvantageous)
    - Increasing the height of a panel → decrease of pillar stresses (advantageous)
    - Barrier pillars for effective isolation of panels and for limiting panel width and negative consequences of pillar failure
  - Total extraction systems → pillar load governed by geometry of total extraction area and relative position of pillars which can change as mining progresses
Thank you for your attention!
Glück Auf!
Pillar strength

- Depends on
  - Rock mass properties
    - Rock strength
    - Rock mass structure
    - Discontinuities (spacing, condition)
    - Water
  - Pillar geometry
    - Cross-section
    - Height (slenderness)
  - Pillar orientation
  - Mine specific, may vary also in same mine significantly

Change of stiffness of surrounding rock mass

- Room and pillar mining operation with underdesigned pillars
  - Hangingwall = very massiv anorthosite
    - High stiffness
    - Stresses redistributed into abutments
    - No consequences of failures of underdesigned pillars
- Mining through fault → No beam building possible anymore
  - Suddenly very soft hangingwall
  - No stress redistribution into abutments anymore
  - Pillar stresses increased drastically
- → Total failure of all pillars and closure of panel