Stability of underground mine development intersections during the life of a mine plan

Abdellah, W., Raju, D., Mitri, H. S., and Thibodeau, D.

Abstract:

The stability of mine developments is of utmost importance during the planned period of production or the life of a mine plan. Many Canadian underground mines use transverse stoping with delayed backfill to extract tabular ore deposits. These methods require access to the orebody through a number of sill drives and cross cuts which link the orezone to the haulage drift hence creating intersections on multiple levels. This paper presents the results of a study on the stability of mine development intersections at Garson Mine of Vale in Sudbury, ON, Canada. Multi-point borehole extensometers (MPBX) are used to monitor the rock deformations of an intersection as mining activities progress. The monitoring results are used to calibrate a multi-level FLAC3D numerical model, which has been developed to assess the stability of the intersection. It is shown that stope extraction causes a lateral shift to the intersection, accompanied by high shear stress in the roof. It is also shown that same-level mining has stronger influence on the stability of the intersection than lower-level mining.

Keywords:

Mine developments; underground mining; deformation monitoring; numerical modelling; rock failure, and Case study.

Published In:

International Journal of Rock Mechanics & Mining Sciences (IJRMMS), 72, 173-181
Abstract:

The purpose of this paper is to establish a qualitative method to estimate the risk level (e.g. rating and ranking) resulting from mining activity. Risk is the product of two factors: probability of failure and cost of consequences. A resultant assessment scale matrix is then used to assign a risk index value which is directly proportional to the potential for excavation instability. A case study, the #1 Shear East orebody at Vale's Garson Mine in Sudbury Ontario will be examined in this paper. A three-dimensional, elastoplastic, finite difference model (FLAC 3D) is presented for a mine development intersection situated 1.5 km below ground surface. The developed assessment scale matrix is used to estimate risk index for intersection (2981) located on 5000 level. The results are presented and categorized with respect to risk-index value, probability of instability, cost of consequence, and mining stage.

Keywords:

Risk-index tool, Cost of consequence, Probability of instability, Numerical modelling, Case study and Underground mine developments.

Published In:

Journal of the Southern African Institute of Mining and Metallurgy (SAIMM). 114, 1-10
Geotechnical Risk Assessment of Mine Development Intersections with respect to Mining Sequence

Abdellah, W., Mitri, H. S., Thibodeau, D. and Moreau-Verlaan, L.

Abstract:

Mine developments such as haulage drifts and their intersections with cross-cuts are the only stope access in sub-level stoping mining system. Thus, they must remain stable during their service life. Haulage drift instability could lead to serious consequences such as: production delay, damage to equipment, loss of reserves and high operational cost. The goal of this paper is the stability of mine developments with respect to mining sequence with focus on the performance of haulage drift intersection during the production plan. A case study, the #1 Shear East orebody at Vale’s Garson Mine in Sudbury Ontario will be examined in this paper. A three-dimensional, elastoplastic, finite difference code (FLAC 3D) is used for this study. The extent of strength-to-stress ratio corresponds to Mohr-Coulomb strength-to-stress ratio of 1.4 is used as failure evaluation criterion. The unsatisfactory performance is reached when the extent of strength-to-stress ratio exceeds the anchorage limit of the rockbolt. Stochastic analysis; adopting Point-Estimate Method (PEM), is then employed with the numerical modelling to tackle the inherent uncertainty associated with rockmass properties. Then, the probability of instability at various mining steps is estimated for the roof and north wall of the studied intersection. The cost of consequence models is introduced to provide an economical solution if the intersection failed, blocked or damaged. Furthermore, the geotechnical risk associated with the instability of mine development intersection is estimated using risk-indexing tool. The results are presented and categorized in terms of probability, cost of consequence and risk-index at various mining stages.

Keywords:

Sub-level stoping mining, Point-Estimate Method (PEM), Cost of consequences, Case study and Risk-indexing tool.

Published In:

Stability of Mine Development Intersections – A Probabilistic Analysis Approach

Abdellah, W., Mitri, H. S., Thibodeau, D. and Moreau-Verlaan, L.

Abstract:

Mine developments such as haulage drifts, cross-cuts and intersections are the only access to valuable ore out of mining zones. They link the mine developments with nearest ore access points. Thus, they must remain stable during their service life or production plan. Mine development instability can cause production delay, loss of reserves, as well as damage to equipment and injury to miners. This paper presents a stepwise methodology to assess the stability of mine development intersections with respect to mine production plan. A case study, the #1 Shear East orebody at Vale's Garson Mine in Sudbury, Ontario, is presented. A three-dimensional, elastoplastic, finite difference model (FLAC 3D) is created to simulate the development of an intersection situated 1.5 km below ground surface. The unsatisfactory performance of the intersection is evaluated in terms of strength-to-stress ratio with respect to mining sequence. A failure criterion is defined by a minimum strength-to-stress ratio of 1.4, is used for mine developments (temporary openings). The intersection stability is evaluated at various mining stages and the modified Point-Estimate of \( (2n+1) \) Method (PEM) is then invoked to study the probability of drift instability at the intersection. The results are presented and categorized with respect to probability, instability, and mining stage.

Keywords:

Mine developments; numerical modelling; and Point-Estimate Method (PEM).

Published In:

Estimating Probability of Instability of Haulage Drift with Respect to Mining Sequences

Abdellah, W., Mitri, H. S., Thibodeau, D. and Moreau-Verlaan, L.

Abstract:

Haulage drifts play a vital role in providing personnel and equipment access to ore extraction areas for mine production. Thus, their stability is of crucial importance during the life of a mine plan. Many Canadian mines use longhole mining methods or one of its variants. These methods require access to the orebody through haulage drifts on multiple levels. This paper examines the stability of mine haulage drifts with respect to planned mining sequence. A case study of an underground mine is presented. The case study examines #1 Shear East of the Garson Mine in Sudbury, Ontario. A two-dimensional, elastoplastic, finite difference model (FLAC 2D) is developed for a haulage drift situated 1.5 km below surface in the footwall of the orebody. The stability of the haulage drift is evaluated in terms of the spread of yield zones into the rockmass due to nearby mining activities. The performance of the drift stability is evaluated at various mining stages, employing the Random Monte Carlo technique (RMC) in conjunction with finite difference modelling to study the probability of unsatisfactory performance of the drift. The results are presented and categorized with respect to probability, instability, and mining stage.

Keywords:

Haulage drifts stability, numerical modeling, RMC, yielding zone.

Published In:

Journal of Civil Engineering and Architecture, ISSN 1934-7359, USA, Volume 7, No. 7 (Serial No. 68), pp. 887-896
Stochastic evaluation of haulage drift unsatisfactory performance using random Monte-Carlo simulation

Abdellah, W., Mitri, H. S., Thibodeau, D., and Moreau-Verlaan, L.

Abstract:

Mine haulage drifts are the primary access to the mining blocks of an orebody in a multilevel mining system of a tabular ore deposit. Drift instability could lead to serious consequences such as injuries, production delays and higher operational cost. In this paper, the haulage drift stability is evaluated on the basis of the primary rock support system comprising 1.8 m resin grouted rebars in the drift walls and 2.1 m long in the drift back. Three failure criteria adopted and compared are Mohr-Coulomb yield zones, elasto-plastic and linear elastic brittle shear failure with respect to lower and same-level mining and filling steps in the vicinity of the haulage drift. The Random Monte-Carlo (RMC) is used in conjunction with finite difference FLAC for random assignment of model input parameters in the FLAC grid. The results are presented in terms of probability of instability and categorized with respect to failure condition and mining step.

Keywords:

Haulage drifts Stability; Numerical modelling; Random Monte-Carlo (RMC); yielding zone, and brittle shear failure.

Published In:

Assessment of Mine Haulage Drift Safety Using Probabilistic Methods of Analysis

Abdellah, W., Mitri, H. S., and Thibodeau, D.

Abstract:

Mine haulage drifts are the arteries of any mine, as they are used to transport the valuable ore out of mining zones, as well as, miners and equipments. Hence, their stability is considered a crucial issue in deep underground mines. Drift instability leads to serious consequences such as injuries, production delays and higher operational cost. This paper examines the issue of haulage drift safety, and probabilistic methods are used to assess the drift failure or unsatisfactory performance. Criteria used to define drift failure conditions are: extent of yielding, and brittle shear failure. The Monte Carlo Simulation (MCS) technique is used in conjunction with finite difference modelling software FLAC for random assignment of model input parameters in the FLAC grid. Comparison between these different failure conditions is carried out to determine the most critical failure or unsafe performance conditions of the mine haulage drift.

Keywords:

Underground Mining, Haulage drifts Stability; Numerical modelling; Monte-Carlo Simulation (MCS).

Published In:

Parametric stability analysis of room and pillar method in deep coal mines

Wael Abdellah

Abstract:

The goal of this paper is, to examine the validity of tributary area method, which is used as an empirical mean to estimate pillar dimensions, in room and pillar mines, taking into consideration a safety factor. A two-dimensional, linear elastic, finite element model (Phase 2D) is created for a simple case of a uniform pattern of room and pillar mine layout, that is lying flat 1200 m below ground surface. Sensitivity analysis has been done to study the effect of horizontal-to-vertical stress ratio, K, on the maximum stress that pillar can sustain without failure. Four cases have been presented in this investigation (K = 0.5, 1, 1.5 and 2). The results reveal that, the maximum stress on the pillar increases as K increases. Alternatively, factor of safety deteriorates as mining depth (i.e., increase of K-value) increases. The results also show that displacements/convergence expand as mining depth goes down.

Keywords:

Sensitivity analysis- Room and Pillar mining-horizontal-to-vertical stress ratio, k

Published In:

Journal of Engineering Sciences- Assiut University- Faculty of Engineering , No. 2- Vol. 43 , PP. 1440 – 1451
Practical application of stochastic methods in geotechnical engineering

Wael Abdellah

Abstract:

Mine haulage drifts are the only stope access in sub-level stoping mining system. Thus, they must remain stable during their service life. Haulage drift instability could lead to serious consequences such as: production delay, damage to equipment, loss of reserves and high operational cost. The goal of this paper is the performance stability evaluation of mine haulage drifts with respect to mining sequence adopting different stochastic methods of analysis. A two-dimensional, elastoplastic, finite difference code (FLAC 2D) is used for this study. Stochastic analysis; adopting Point-Estimate Methods (PEMs), Monte-Carlo Simulation (MCS) and Random Monte-Carlo Simulation (RMCS) are then employed with the numerical modelling to tackle the inherent uncertainty associated with rockmass properties. Then, the probability of instability at last mining step (e.g., after excavating stope 3) is estimated for haulage drift side walls and roof. The stability indicators are defined in terms of displacement, stress and the extent of yield zones, which are adopted as a basis for assessing the performance stability of haulage drift. The stochastic results are presented and compared in terms of probability of occurrence at last mining stage (e.g., after excavating stope 3) adopting displacement/convergence criterion.

Keywords:

Probabilistic Methods- Performance stability of Haulage drift

Published In:

Journal of Engineering Sciences- Assiut University-Faculty of Engineering, No. 1 - Vol. 43, PP. 57 – 70
Numerical modelling stability analyses of haulage drift in deep underground mines

Wael Abdellah

Abstract:

Mine haulage drifts are the arteries of a mine. They are used for the transportation of blasted ore from the draw point to nearby ore pass or dumping point in deep underground mines. Thus, they must be remained functional during their service life. Otherwise, their instability could lead to serious consequences such as injuries, delay of production and increased operational cost. The objective of this paper is to evaluate the performance stability of mine haulage drifts with respect to mining step adopting numerical modeling of analysis. A two-dimensional, elastoplastic, finite difference code (FLAC 2D) is built for the purpose of this study. Haulage drift performance is evaluated using stability indicators and numerical modeling results are presented in terms displacement, stress and the extent of yield zones with respect to mining step.

Keywords:

Mine haulage drift-displacement/convergence criteria-stress distribution-extent of yield zone function

Published In:

Journal of Engineering Sciences-Assiut University-Faculty of Engineering, No.1- Vol. 43, PP. 71 – 81
Haulage drift stability analysis-A sensitivity approach

Wael Abdellah

Abstract:

Haulage drifts are the primary access to the mining blocks of an ore body in a multi-level mining system of a tabular ore deposit. Drift instability could lead to serious consequences such as injuries, production delays and higher operational cost. Rockmass properties are significant geotechnical design input parameters. These parameters are never known precisely and always uncertainties associated with them. The stability of the haulage drift is examined through parametric study of a nonlinear, elastoplastic, two-dimensional finite element model representing typical mining layout most commonly adopted in Canadian underground metal mines. The parametric study examines the influence of footwall rockmass geomechanical properties (e.g., cohesion, friction angle, dilation angle and Young's Modulus) and the mining depth (e.g., horizontal-to-vertical stress ratio). Stability indicators are defined in terms of displacement, stress and the extent of yield zones, which adopt as a basis for assessing the effect of different parameter on the stability of haulage drift.

Keywords:

Haulage drifts stability, Numerical modelling, sensitivity analysis, and stability indicators.

Published In:

24th International Mining Congress and Exhibition of Turkey, Antalya, Turkey, April 14-17, 2015, Pp. 499-507
Probabilistic stability analysis of mine haulage drifts in sublevel stoping system.

Abdellah, W., and Mitri, H. S.

Abstract:

Mine haulage drifts are the primary access to the mining blocks of an ore body in a multi-level mining system of a tabular ore deposit. Drift instability could lead to serious consequences such as injuries, production delays and higher operational cost. A nonlinear, elastoplastic, two-dimensional finite element model is created to represent typical mining layout most commonly adopted in Canadian underground metal mines. Mohr-Coulomb yielding failure criterion is adopted with respect to lower and same-level mining and filling steps in the vicinity of the haulage drift. The haulage drift stability is evaluated on the basis of the primary rock support system comprising 1.8m resin grouted rebars in the drift walls and in the back. For the purpose of this study, the minimum anchorage length of rock support is taken as 30 cm (12-inch). The drift unsatisfactory performance occurs when the extent of yielding exceeds 1.5m resulting in insufficient anchorage length beyond the yield zone. The probabilistic method of analysis is then invoked to study the probability of unsatisfactory performance of the haulage drift. The results are presented and categorized with respect to probability, instability, and mining stage.

Keywords:

Haulage drifts stability, Numerical modelling, Yielding zones, and Point-Estimate Method (PEM)

Published In:

12th International Conference on Mining, Petroleum & Metallurgical Engineering (October 20th - 22th, 2014), Suez, Egypt (accepted).
Stochastic Stability Analysis of Mine Developments with Respect to Planned Mining Sequence.


Abstract:

Underground mine developments, such as haulage drifts and cross cuts, play a vital role in providing access to ore extraction areas for mine production. The stability of mine developments is thus of crucial importance during the life of a mine plan. Many Canadian mines use longhole mining methods or one of its variants. These methods require access to the orebody through mine developments such as haulage drifts and cross cuts on multiple levels. This paper examines the stability of mine development access intersections with respect to the planned mining sequence. A case study, the #1 Shear East orebody at Vale's Garson Mine in Sudbury, Ontario, is presented. A three dimensional, elastoplastic, finite difference model (FLAC 3D) was created for a development intersection situated 1.5 km below ground surface. The stability, or performance of the intersection, is evaluated in terms of the strength-to-stress ratio. The ratio threshold is set at 1.4 for temporary openings. Unsatisfactory performance is defined as a strength-to-stress ratio less than this threshold value. The performance of the intersection stability is evaluated at various modelled mining stages and the probabilistic method of analysis is then invoked to study the probability of unsatisfactory performance of the intersection. The results are presented and categorized with respect to probability, instability, and mining stage.

Keywords:

Mine developments, underground mining, numerical modelling, Probabilistic method of analysis (PEM)

Published In:

23rd world mining congress (WMC), Montreal, Quebec, Canada, August 11-15, 2013 (Accepted). Paper No. 170.
Comparison of Two Failure Criteria for the Assessment of Haulage Drift Stability Using Stochastic Analysis and Numerical Modelling

Wael Abdellah, Hani S. Mitri, Denis Thibodeau, Lindsay Moreau-Verlaan

Abstract:

Mine haulage drifts are the primary access to the mining blocks of an orebody in a multilevel mining system of a tabular ore deposit. The stability and functionality of haulage drifts are thus crucial to the success of a mining operation. Drift instability could lead to serious consequences such as injuries, production delays and higher operational cost. In this paper, the performance of the haulage drift stability is evaluated on the basis of the primary rock support system comprising 1.8 m resin grouted rebars in the drift walls and 2.1 m long bolt in the back. Two failure criteria namely the extent of Mohr-Coulomb yield zones around the drift, and linear elastic brittle shear failure are adopted and compared, with respect to lower level and same-level mining and filling sequence in the vicinity of the haulage drift. The case study is one of the #1 Shear East zone of the Garson Mine in Sudbury, Ontario. Random Monte Carlo (RMC) technique, which has been previously established to assess the haulage drift stability, is employed in this investigation. The RMC technique is used in conjunction with finite difference modelling software FLAC for random assignment of model input parameters in the FLAC grid. Deterministic model results reveal the drift behaviour in terms of deformation (convergence) and mining-induced stress distribution. Comparison between the two different criteria is carried out to determine which method is most suitable in evaluating unsatisfactory drift performance. The results are presented in terms of probability of instability and categorized with respect to failure condition and mining step. It is shown that the brittle shear failure condition based on linear elastic response calls for enhanced support system at a later mining step than what Mohr-Coulomb yielding condition does. The paper presents a detailed discussion of the stochastic analysis results.

Published In:

In Proceedings of 21st Canadian Rock Mechanics Symposium, RockEng12, Edmonton, AB, Canada, May 5-9, Editor Chris Hawkes, Associate Editors, Derek Kinakin, Sam Proskin, Denis Thibodeau, pp. 41-51.
Estimating Probability of Instability of Haulage Drift with Respect to Mining Sequences.


Abstract:

Haulage drifts play a vital role in providing personnel and equipment access to ore extraction areas for mine production. Thus, their stability is of crucial importance during the life of a mine plan. Many Canadian mines use longhole mining methods or one of its variants. These methods require access to the orebody through haulage drifts on multiple levels. This paper examines the stability of mine haulage drifts with respect to planned mining sequence. A case study of an underground mine is presented. The case study examines #1 Shear East of the Garson Mine in Sudbury, Ontario. A two-dimensional, elastoplastic, finite difference model (FLAC 2D) is developed for a haulage drift situated 1.5 km below surface in the footwall of the orebody. The stability of the haulage drift is evaluated in terms of the spread of yield zones into the rockmass due to nearby mining activities. The performance of the drift stability is evaluated at various mining stages, employing the Random Monte Carlo technique in conjunction with finite difference modelling to study the probability of unsatisfactory performance of the drift. The results are presented and categorized with respect to probability, instability, and mining stage. RéSUMÉ Les galeries de halage jouent un rôle vital permettant l'accès des opérateurs et de l'équipement dans les zones d'extraction. Ainsi, leur stabilité est d'une importance cruciale au cours de la vie de la mine. Plusieurs mines canadiennes utilisent la méthode d'exploitation long-trous ou une de ses variantes. Ces méthodes nécessitent l'accès à la zone minéralisée à travers les galeries de halage sur plusieurs niveaux. Ce document examine la stabilité des galeries de halage des mines en fonction en considérant la séquence minière prévue. Une étude de cas de la zone n ° 1 de cisaillement Est, de la mine souterraine Garson à Sudbury, Ontario, est présentée. Un modèle de différence finie de deux dimensions élastoplastique (FLAC 2D) est développé pour une galerie de halage située à 1,5 km sous la surface (in the footwall of the orebody). La stabilité de la galerie de halage est évaluée en termes de l'extension des zones de rendement dans la masse rocheuse en raison des activités minières à proximité et par rapport à un système de soutien de roche primaire comprenant 2,4 m et 2,1 m de résine coulis barres dans le dos de dérive et les murs de dérive, respectivement. La performance de la stabilité de la galerie est évaluée à différentes étapes de minages, en employant la méthode aléatoire de Monte Carlo en conjonction avec le logiciel de modélisation de différences finies FLAC 2D pour étudier la probabilité d'un rendement insatisfaisant de la stabilité de la galerie. Les résultats sont présentés et classés selon la probabilité, l'instabilité, et l'étape de l'exploitation minière.

Published In:

In Proceedings of the 65th Canadian Geotechnical Conference - GeoManitoba2012, September 30 to October 3, Winnipeg, Canada, G. Robinson and K. Bannister (eds), Paper No. 305 (pp.1-5). Published by the Canadian Geotechnical Society. , 305 , 1-5
"Geotechnical Risk Assessment of Mine Developments in Deep Metal Mines".

Wael Rashad Elrawy Abdellah

Abstract:

Mine developments such as haulage drifts and cross-cuts are the primary access to the mining blocks of an orebody in multilevel mining systems for tabular ore deposits. Thus, their stability is of utmost importance during the planned period of production or the life of a mine plan. Many Canadian underground mines use longitudinal and transverse stoping with delayed backfill to extract tabular ore deposits. These methods require access to the orebody through a number of sill drives or crosscuts which link the orezone to the haulage drift hence creating intersections on multiple levels. Mine development instability could lead to serious consequences such as injuries, production delays and higher operational cost. The objective of this research is to develop a hybrid approach in which deterministic numerical modelling is integrated with probabilistic methods to evaluate the stability of mine developments due to nearby mining activity. A case study comprising four consecutive mine levels in a deep underground metal mine in Sudbury, Ontario has been adopted for this study. The stability performance of the haulage drift is assessed using two separate evaluation criteria, namely Mohr-Coulomb yield function and Brittle Shear Failure. Random Monte-Carlo (RMC) technique is then employed in conjunction with Finite difference modelling software FLAC to determine the probability of instability or unsatisfactory performance of the haulage drift with respect to nearby mining sequence. In this study, the haulage drift performance is considered unsatisfactory when the yield zones or brittle shear failure around the haulage drift extend beyond the anchorage limit of the rock support. A comparison of the results from Mohr-Coulomb and Brittle Shear conditions has revealed that Mohr-Coulomb is more conservative from a design point of view. A three-dimensional, elastoplastic, finite difference model (FLAC 3D) is then constructed to simulate the case study mining orezone. The unsatisfactory performance of the intersection is evaluated with respect to mining sequence in terms of the strength-to-stress ratio computed by FLAC3D. Unsatisfactory stability performance is defined by a strength-to-stress ratio that is less than 1.4 and its corresponding extent into the rockmass around the intersection. Due to the large size of the FLAC3D model, the probabilistic simulations are conducted with the Point-Estimate Method (PEM), which requires significantly lesser number of simulations than Random Monte-Carlo (RMC). The results are presented and categorized with respect to probability, instability, and mining stage. In order to validate the numerical model, Multi-point borehole extensometers (MPBX) are installed at selected intersections to monitor the rock deformations as mining activities progress. The monitoring results revealed a lateral shift of the drift walls toward the orebody and much less deformations in the drift back. Finally, a methodology is developed to estimate the geotechnical risk of drift instability by considering the probability of failure and cost of consequence of such failure at an intersection. A 5-level risk index is derived which ranges from low to extreme. The methodology is demonstrated through an intersection from the case study mine, and the risk index is shown to vary with mining sequence. It is shown that the risk-index methodology can be used to confirm the need for enhanced supports, but it can also be used as basis for the comparison alternative mine designs.

Keywords:

Risk Indexing tool- Mine Developments- Geotechnical Engineering- Numerical Modelling- Stochastic Analysis- FLAC 2D 
&3D.

Published In:

assessment-of-mine-developm , , Pp:1-268
"Applications of Finite Element Methods in Rock Mechanics".

Hani S. Mitri

Abstract:

The purpose of the book is to introduce the students, geologists, and engineers to the fundamentals of the finite element method and its application in the field of geotechnical engineering with emphasis on rock mechanics. They learn the necessary principles to help them use commercially available programs or to create their own basic finite element code for the stress and deformation analysis of solid structures. The topics covered in this book are: Introduction to numerical methods, displacement Finite element method, equilibrium equations, elasticity relations, formulation procedure (solid mechanics), shape functions, stiffness matrix, load vectors, mesh convergence and accuracy, isoparametric element and numerical integration.

Keywords:


Published In:

Verlag/Publisher: LAP LAMBERT Academic Publishing. ist ein Imprint der/is a trademark of OmniScriptum GmbH & Co. KG. Heinrich-Bocking-Str. 6-8, 66121 Saarbrücken, Deutschland/ Germany. Herstellung: siehe letzte Seite. ISBN-13: 978-3-659-36806-6 , NULL , Pp. 1-149
ABSTRACT Mine developments such as haulage drifts and cross-cuts are the primary access to the mining blocks of an orebody in multilevel mining systems for tabular ore deposits. Thus, their stability is of utmost importance during the planned period of production or the life of a mine plan. Many Canadian underground mines use longitudinal and transverse stoping with delayed backfill to extract tabular ore deposits. These methods require access to the orebody through a number of sill drives or cross-cuts which link the orezone to the haulage drift hence creating intersections on multiple levels. Mine development instability could lead to serious consequences such as injuries, production delays and higher operational cost. The objective of this research is to develop a hybrid approach in which deterministic numerical modelling is integrated with probabilistic methods to evaluate the stability of mine developments due to nearby mining activity. A case study comprising four consecutive mine levels in a deep underground metal mine in Sudbury, Ontario has been adopted for this study. The stability performance of the haulage drift is assessed using two separate evaluation criteria, namely Mohr-Coulomb yield function and Brittle Shear Failure. Random Monte-Carlo (RMC) technique is then employed in conjunction with Finite difference modelling software FLAC to determine the probability of instability or unsatisfactory performance of the haulage drift with respect to nearby mining sequence. In this study, the haulage drift performance is considered unsatisfactory when the yield zones or brittle shear failure around the haulage drift extend beyond the anchorage limit of the rock support. A comparison of the results from Mohr-Coulomb and Brittle Shear conditions has revealed that Mohr-Coulomb is more conservative from a design point of view. A three-dimensional, elastoplastic, finite difference model (FLAC 3D) is then constructed to simulate the case study mining orezone. The unsatisfactory performance of the intersection is evaluated with respect to mining sequence in terms of the strength-to-stress ratio computed by FLAC3D. Unsatisfactory stability performance is defined by a strength-to-stress ratio that is less than 1.4 and its corresponding extent into the rockmass around the intersection. Due to the large size of the FLAC3D model, the probabilistic simulations are conducted with the Point-Estimate Method (PEM), which requires significantly lesser number of simulations than Random Monte-Carlo (RMC). The results are presented and categorized with respect to probability, instability, and mining stage. In order to validate the numerical model, Multi-point borehole extensometers (MPBX) are installed at selected intersections to monitor the rock deformations as mining activities progress. The monitoring results revealed a lateral shift of the drift walls toward the orebody and much less deformations in the drift back. Finally, a methodology is developed to estimate the geotechnical risk of drift instability by considering the probability of failure and cost of consequence of such failure at an intersection. A 5-level risk index is derived which ranges from low to extreme. The methodology is demonstrated through an intersection from the case study mine, and the risk index is shown to vary with mining sequence. It is shown that the risk-index methodology can be used to confirm the need for enhanced supports, but it can also be used as basis for the comparison alternative mine designs.

Abstract: (18)

Geotechnical Risk Assessment of Mine Haulage Drifts during the Life of a Mine Plan

Wael Abdellah

RÉSUMÉ Les développements miniers tels que les galeries de roulage et les travers-bancs constituent les accès principaux au gisement lors de l'exploitation d'un gisement tabulaire sur plusieurs niveaux. C'est pourquoi leur stabilité est d'une importance primordiale pendant la période de production ou pendant la planification d'une exploitation. De nombreuses mines souterraines canadiennes emploient des méthodes d'abatage par chambres avec remblayage différé pour exploiter les gisements tabulaires. Ces méthodes nécessitent un accès au gisement par de nombreux travers-bancs qui relient le gisement aux galeries de roulage, créant des intersections à de nombreux niveaux. L'instabilité de ces galeries peut conduire à de graves conséquences mettant en jeu la sécurité du personnel, à des retards de production et à des coûts d'exploitation plus importants. L'objectif de cette recherche est de développer une approche hybride, basée sur une modélisation numérique déterministe intégrant des méthodes probabilistes, pour évaluer la stabilité d'une galerie d'avancement en fonction de la proximité de l'activité minière. Nous présentons une application à une mine métallique située à Sudbury, en Ontario, dans laquelle l'exploitation est réalisée sur 4 sous-niveaux. La stabilité d'une galerie de roulage est calculée à partir des 2 critères suivants: critère de plasticité de Mohr-Coulomb et « Brittle Shear Failure ». La méthode de simulation aléatoire de Monte Carlo (RMC) est utilisée conjointement avec le logiciel de différences finies FLAC pour déterminer la probabilité d'instabilité de la galerie de roulage en fonction de la séquence d'exploitation choisie. La stabilité de la galerie de roulage est considérée comme non satisfaisante dès lors que la zone de plasticité autour de la galerie excède la longueur des boulons. Une comparaison entre les critères d'évaluation montre que le critère de plasticité est le plus sécuritaire.
pour témoigner de l'influence de la séquence d'exploitation. Un modèle élasto-plastique en 3 dimensions, calculé par la méthode des différences finies (FLAC-3D), est créé pour simuler le cas d'application. La performance insatisfaisante d'une intersection est évaluée au moyen du ratio contrainte/résistance. La stabilité non satisfaisante est définie par un ratio inférieur au seuil de 1,4 et par l'étendue de la zone correspondante autour de l'intersection. Du fait de la grande taille du modèle numérique, les simulations probabilistes sont réalisées avec la méthode d'estimation ponctuelle qui nécessite un nombre significativement moins important de calculs que la méthode de Monte-Carlo aléatoire. Les résultats sont présentés et classés selon leurs probabilités, leur degré d'instabilité et l'état d'avancement de la séquence d'exploitation. Des extensomètres de forage à points de mesure multiples (MPBX) sont utilisés pour mesurer les déformations rocheuses d'une intersection au fur et à mesure de l'excavation. Les résultats sont utilisés pour calibrer le modèle FLAC-3D. L'auscultation a montré l'existence d'un déplacement latéral des parois de la galerie de roulement en direction du gisement et une déformation moindre du toit. Le coût des conséquences de la rupture d'une intersection est estimé par le coût de développement d'un contournement. Une échelle de risque à 5 niveaux, allant de « faible » à « extrême », est proposée. Cette échelle de risque est appliquée à une intersection de la mine étudiée et on montre que le niveau de risque dépend de la séquence d'exploitation. On montre également que cette méthodologie peut être mise en œuvre afin de confirmer la nécessité d'un soutènement amélioré. Elle peut aussi servir pour la comparaison entre différentes méthodes d'exploitation.

Keywords:


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Abstract:

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MSc. in Drilling Engineering- Department of Mining and Metallurgy, University of Assiut, Assiut, Egypt. , NULL , NULL
Estimating the probability of unsatisfactory performance associated with the instability of mine developments

Wael Abdellah and Hani Mitri

Abstract:

ABSTRACT Mine developments are the main access to extract tabular ore deposits in deep underground mines. Therefore, their stability is considered the principal priority during the mine production plan. The success of ore extraction mainly depends on the stability and serviceability of mine developments. Mine development instability is expensive and is a risk to personnel and equipment and in turn, it raises operational costs (e.g., repair costs, slashing, rehabilitation costs, costs of adding secondary support, miners wages and delay of production) (Ellefmo, and Eidsvik, 2009; Abdellah et al. 2014a; 2014b; 2014c). This paper aims to develop a hybrid approach in which deterministic numerical modelling is integrated with probabilistic methods to estimate the probability of unsatisfactory performance (e.g., rating and ranking) associated with the instability of mine developments with respect to mining sequences adopting Rosenblueth's Point-Estimate Method (RPEM). A three-dimensional, elastoplastic, finite difference model (FLAC3D) is created (Itasca, 2009). The results are presented and categorized with respect to the probability of instability and the mining stage.

Keywords:

KEYWORDS: Mine developments; numerical modelling; Rosenblueth's Point-Estimate Method (RPEM); probability of unsatisfactory performance

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3rd International Symposium on Mine Safety, Science and Engineering (ISMS2016)- August 13-19, 2016, McGill University, Montreal, Quebec, Canada , NULL , 84-89
Drillability prediction using regression analysis for some Egyptian rocks

Abstract:

Abstract Drilling and blasting operation are an essential and integral part of mining cycle/process. They are almost employed in all mining methods (e.g., surface and underground works) as well some civil engineering projects (e.g., dams, roads construction and tunnel excavation). In feasibility studies (e.g., planning and preliminary cost estimation), the rock penetration rate (e.g., drillability) is used as a tool to predict the rock mass strength properties/characteristics. This paper examines the relationship between strength properties of selected rocks in Egypt and their drillability. Six natural rock types; were selected from different locations in the country, and another five artificial rocks; prepared in the lab with different composition, were tested in the laboratory for uniaxial compressive strength, tensile strength, shear strength, hardness (e.g., point load strength and impact strength) and rate of penetration. The regression equation is then established from the relationship between strength properties of rock and the penetration rate. The results revealed that strong correlation exists between penetration rate and compressive and tensile strength with correlation coefficient of $R^2 \geq 0.75$ for both exponential and logarithmic functions. For Brazilian tensile strength, the correlation coefficient was of $R^2 \geq 0.7$. The relationship between specific energy (SE) and rock strength properties are also presented and discussed in this study, where the results showed strong correlation.

Keywords:

Keywords: Drillability, Rock Strength Properties, Specific Energy (SE), Regression Analysis.

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Evaluation of the Effect of Rock Joints on the Stability of Underground Tunnels

Wael R. Abdellah, Mahrous A. M. Ali, Gamal Y. Boghdady and Mohamed E. Ibrahim

Abstract:

The quality of rock mass has significant impacts on the stability of underground excavations. Rock mass is a matrix consisting of rock material and discontinuities/fractures (e.g., faults, joints). Such these discontinuities are source of weakness (e.g., large displacements and rotations may occur across them), consequently; they may lead to crucial instability problems. The objective of this paper is to assess the stability of underground tunnel which is excavated between two inclined planes of weakness (rock joints). The numerical modelling analysis has been conducted using RS2D software adopting elasto-plastic Mohr-Coulomb criterion. The rock joints are allowed to slip to investigate their influence on the stress distribution and deformation close to the excavated tunnel. The stability of underground tunnel has been assessed by investigating; extent of plastic zones, distribution of the induced stress and displacements in the surrounding rock mass and along rock joints. The results reveal that, the normal stress along rock joints is sharply dropped where joints pass over the excavation; Slip occurs (e.g., indicated by inward displacement of rock on the underside of the plane of weakness) over the excavation due to reversal direction of the shear stress and the maximum shear displacements occur above and below the tunnel.

Keywords:

Tunnelling, numerical modelling, geometrical properties of rock joints, extent of plastic zones, induced stress and rock mass deformation.

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Journal of Civil Engineering and Architecture Research, Vol. 3, No. 11, pp. 1790-1799
Stability Analysis of Vertical and Inclined Backfilled Stope

Wael R. Abdellah & Mahrous A. Ali

Abstract:

Sublevel stoping mining with delayed backfill is a widely employed method in many Canadian underground metal mines (e.g., Bosquet, Doyen, Laronde, and Lapa mines in Quebec and Garson, Creighton, Red lake and David bell mines in Ontario). In this method, the extracted stope(s) must be tightly backfilled before advancing to extract the adjacent secondary stope(s). Thus, backfill is necessary to provide good confinement to the host rock mass. Therefore, its objective is to maintain the stability of mined out stope(s). Otherwise, the failure of backfill column into adjacent stope(s) leads to higher operation cost (e.g., cost of ore milling/ore processing operation, costs associated with ore dilution when waste/backfill material mixed with unmined block(s)). Consequently, backfill instability could lead to an overall unsafe/interrupt mining operation. This article presents the results of numerical modelling analysis to evaluate the performance stability of vertical and inclined backfilled stope adopting stress state distribution. Two-dimensional finite element model is built to conduct linear elastic analysis employing RS2D program (e.g., formerly known as phase2D). The results are presented and discussed in terms of vertical stress and absolute total displacement.

Keywords:

Backfill performance evaluation, Stress state into backfilled stope, Numerical modelling, sublevel stoping mining system

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Journal of Engineering Sciences (JES) , Vol. 45, No. 1 , PP. 70–79
Serviceability analysis of deep underground openings driven in jointed-rock

Wael R. Abdellah

Abstract:

The performance of underground excavations is inevitably influenced by rock mass characteristics, presence of joints and their geometrical properties, depth below surface and state of in-situ stress field. The objective of this paper is to investigate the behaviour of deep underground tunnel opening existed between two bedding planes. Such planes weaken the strength of rock mass and may cause rock slippage/rotation along them. Therefore, the state of stress-displacement, after tunnel opening has been introduced, is examined using two-dimensional elasto-plastic finite-elements code, RS2D. The results indicate that, there is significant drop in the normal stress along joints over tunnel opening; slip occurs due to reversal in the direction of shear stress (e.g., inward shear displacement is produced) and there is discontinuity in the strength contours of rock surrounding tunnel after they have been intersected by bedding planes.

Keywords:

State of stress-displacement Bedding planes Tunnel performance Depth of failure zones Stability analysis

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International Journal of Mining Science and Technology (IJMST) , 27 , 1019-1024
Studying the effect of some parameters on the stability of shallow tunnels

Wael R. Abdellah, Mahrous A. Ali, Hyung-Sik Yang

Abstract:

Several factors have crucial impact on the serviceability of underground openings including: the quality of rock mass; the presence of rock joints and their geometrical properties; the state of in-situ stress ratio; the depth below surface and opening geometry. This paper only investigates the effect of two parameters on the stability of underground shallow tunnels, namely: the presence of rock joints in the rock mass matrix and the shape of the excavation. A series of two-dimensional elasto-plastic finite-element models has been constructed using rock-soil, RS2D, software. Consequently, parametric stability analysis has been conducted for three different tunnel shapes (e.g. circular, square and horseshoe) with/without joint inclusion. Four reference points have been assigned in the tunnel perimeter (e.g. back, sidewalls and floor) to monitor the state of stress-displacement in the rock mass around them. The results indicate that the weak performance of a tunnel opening occurs with a square-shaped opening and when joints exist in the rock mass. In addition, the normal stress along joints sharply drops in the vicinity of a tunnel opening. Moreover, the direction of shear stress is reversed. Thus, it causes inward shear displacement.

Keywords:

Tunnel shape, Rock joints, Numerical modelling, Stability indicators

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Journal of Sustainable Mining, 17 (2018), 20-33
Evaluation of open pit slope stability using various slope angles and element types

W.R. Abdellah, M.M. Beblawy, M.T. Mohamed

Abstract:

The success of mining operation primarily is measured by safety and productivity. Rock slope stability is the major concern in open pit mines. Slope instability results in damage to equipment, injuries to personnel, disruption to mining operation and loss overall mine profitability. The objective of this study is to demonstrate a method to select the optimal slope angle related to three principal factors: safety, productivity and mining costs. Also, it aims to investigate the accuracy of numerical analysis using different element types and order. Therefore, series of two-dimensional elasto-plastic finite-element models has been constructed at various slope angles (e.g. 400, 450, 500, 550, 600, 650, and 700) and different element types (e.g. 3-noded triangle (T_3), 6-noded triangle (T_6), 4-noded quadrilateral (Q_4) and 8-noded quadrilateral (Q_8)). The results are presented, discussed and compared at various slope angles and element types in terms of critical strength reduction factor (CSRF) or its equivalent factor of safety (FOS), total rock slope displacement, mine production and mining costs. The results reveal that, the mine productivity increases as slope angle increases, however, slope stability deteriorates. Alternatively, the factor of safety (FOS) decreases as slope angle becomes steeper (e.g. minimum factor of safety is obtained at highest steep angle of 700). Despite of the increasing in computation time, the analysis shows that, the accuracy of the modelling increases when adopting high-order element types (e.g. 8-noded quadrilateral and 6-noded triangle elements).

Keywords:

Slope stability, open pit mine, critical strength reduction factor (CSRF), open pit excavation sequence, FEM element type/order

Published In:

Mining of Mineral Deposits, Volume 12 (2018), Issue 2, pp. 47-57
Abstract:

ABSTRACT Purpose. The objective of this study is to determine the best operating conditions for the most notable drilling parameters (i.e. weight on bit (WOB), rotary drilling speed (RPM), and characteristics of drilling fluid) using field data obtained from El-Sharara Oil Field. Methods. The used data has been extracted from daily drilling reports of well named (NC-186/K04h) field. Such data contains information about the geological formations, casing strings, drill-bits, fuel consumption, flow rate of drilling fluid and other drilling parameters. Findings. The results reveal that, the lower geological formations of El-Sharara Oil Field, the harder are the upper formations. Therefore, it is recommended to apply heavy loads (i.e. WOB of 45000 lb) with low drilling speed (i.e. 100 rpm) in the lower formations; and to apply small loads (i.e. WOB of 19000 lb) with high drilling speed (i.e. 160 rpm) in the upper formations. Originality. This study evaluates the performance of drilling operation based on the interaction between rock formations and machine drilling parameters. Practical implications. Understanding such interaction between rock formations and machine drilling parameters will remarkably improve the rate of penetration (ROP) in the related geological formations. Consequently, the overall drilling costs will be reduced in terms of drilling time, life of drill-bit and fuel consumption.

Keywords: improvement of drilling operation, operating parameters, rock properties, oil well drilling, El-Sharara Oil Field

Published In:

Numerical modelling of staged stope extraction in a tabular steeply dipping deposit

Wael R. Abdellah, Haitham M. Ahmed & Mohammed A. Hefni

Abstract:

ABSTRACT Stope stability is a key factor for the success of a mining operation. To optimise ore productivity while maintaining stope stability, the mining block/stope must be extracted in stages. Ore dilution will occur if the stope is not properly excavated/blasted. This study examines stope stability during mining in three stages, where the height of each stage stope is 10 m. The paper also presents simulation analysis of a typical steeply dipping tabular orebody at 1200 m depth below the surface, which is common in many Canadian underground hard rock mines. Numerical modelling analysis was conducted using the finite element program, RS2D, where the non-linear elasto-plastic Mohr-Coulomb failure criterion was adopted. The rock reinforcement system (i.e. cable bolts) was modelled/installed in the stope footwall after each mining stage to strengthen access drifts and stabilise the rock mass around the stope that was disturbed by mining activity. Results are discussed in terms of depth of failure zones, total deformation and axial forces in cable bolts with respect to mining stage.

Keywords:

Steeply dipping tabular deposit; numerical modelling; depth of failure zones; axial forces in cable bolts

Published In:

Optimization of Blending Operation for Aswan Phosphate Mines Using Linear Programming


Abstract:

ABSTRACT Purpose. The economic value of phosphate is reduced when randomly blending raw phosphate produced from different mines. Therefore, the blending process of different raw phosphate ores to produce economic percentage of P2O5 is essential to maximize the profit of a mine. Methods. This paper presents an application of Linear programming (LP) method to determine the optimum quantities of phosphate ore needed per each mine for blending process. Three phosphate operations, located in Aswan province south of Egypt, have been chosen for this study namely B1, B2 and C. Findings. The results of LP methods reveal that the phosphate ore of 24% of P2O5 will be produced by blending 16.8% of phosphate ore from operation B1, 9.42% of phosphate ore from operation B2 and 73.78% of phosphate ore from operation C. whilst the phosphate ore of 22% P2O5 will only be obtained by blending 66.43% of phosphate ore from operation B1 and 33.57% from mine B2. Originality. Using the linear programming by applying solver function in mine operations. Practical implications. Applied linear programming in mining as regard mining operations to obtain the optimum solution in mining sites.

Keywords:

Keywords: linear programming, blending operation, profit optimization, phosphate ore deposit

Published In:

Mining of Mineral Deposits, Volume 12 (2018), Issue 4, pp. 1-8
Parametric stability analysis of pillar performance at Nohyun limestone mine, South Korea—a case study

Kim, JG., Abdellah, W.R. & Yang, HS.

Abstract:

The objective of this paper is to evaluate the performance of pillars located on level #3 at Nohyun Limestone Mine that uses the room-and-pillar method. The mine is located at South of Cheongju city, North Chungcheong Province, South Korea. A series of two-dimensional elasto-plastic finite-difference models has been constructed using FLAC2D software. Factor of safety (FOS) is then calculated using fish-code (solve FOS), an internal command of FLAC built on a shear strength reduction technique. The results are presented and discussed in terms of stress state, deformation and factor of safety with respect to mining sequence, mining depth and mineshaft width. The results reveal that, the stability of pillars deteriorates when level #3 is entirely mined out after extracting level #2 (i.e. FOS =1.33 to 1.55). In addition, the safety of pillars is sharply dropped (i.e. FOS =1.16 to 1.33) when mining depth extends to 15m; and similarly, width of mineshaft increases by 2m. Also, a comparison of calculation of safety factor, FOS, employing numerical modelling (i.e. FOS =1.16 to 1.86) and analytical methods (i.e. FOS = 7.35 to 36.36) has revealed that numerical modelling is more conservative from a design point of view. The study also indicates that, the overall mine stability is influenced by the discordance in the pillar arrangement between adjacent levels. Therefore, it is recommended that, the pillar design should be dictated by the inclination of the orebody.

Keywords:

Room-and-pillar method, parametric stability analysis, factor of safety (FOS), Nohyun Limestone Mine.

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