BIBLIOGRAPHY ON HEAT FLOW AND PROBLEMS IN COLD MINES

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BIBLIOGRAPHIE SUR LES TRANSFERTS DE CHALEUR ET LES PROBLÈMES DANS LES MINES FROIDES

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Canadian Mine Technology Laboratory / Laboratoire canadien de technologie minière

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ABSTRACT

The purpose of this bibliography is to assemble the published reports of possible interest to studies of heat related problems in cold mines, i.e. those working in permafrost, where it is essential to prevent thawing of interstitial ice in rock or backfill because of the potential creation of rock falls. The themes considered are :

1. Theory of heat flow.
2. Measurements of heat flow in mines.
3. Computer modelling and calculations of heat flow.
4. Thermal properties of rocks.
5. Psychrometry and enthalpy.
6. Ventilation computer modelling.
7. Design of mine ventilation and cooling systems.
8. Strength of ice-rock mixtures.
9. Related miscellaneous topics.

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KEYWORDS: Cold mines, heat flow, frozen backfill, computer simulation, thermal properties, ventilation, bibliography.

BIBLIOGRAPHIE SUR LES TRANSFERTS DE CHALEUR ET LES PROBLÈMES DANS LES MINES FROIDES

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RESUME

Le but de cette bibliographie est de rassembler si possible les rapports publiés d'études sur les problèmes de chaleur dans les mines froides, p. ex., dans le pergélisol, où il est essentiel de prévenir la fonte de la glace interstitielle dans la roche ou le remblai, à cause des risques d'éboulements de roche. les thèmes considérés sont:

1. la théorie des transferts de chaleur
2. la mesure des transferts de chaleur dans les mines
3. la simulation numérique et le calcul des transferts de chaleur dans les mines
4. les propriétés thermiques des roches
5. la psychrométrie et l'enthalpie
6. la simulation numérique de la ventilation
7. la conception des systèmes de ventilation et de climatisation dans les mines
8. la résistance des melange roche-glace
9. sujets connexes divers

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MOTS CLES: mines froides, transferts de chaleur, remblai gelé, simulation sur ordinateur, propriétés thermiques, ventilation, bibliographie.

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INTRODUCTION

Canada has a large area of land in the permafrost region. There are many potential mines in this area. Mining in permafrost ground has specific problems in regard to stability of mine excavations. In many cases it may be essential to prevent thawing of the ice in the rock interstices. The particular starting point for this bibliography was the desire of one northern mine to freeze backfill in its stopes for subsequent mining of the adjacent pillars. This bibliography is concerned with the passage of heat through the rock and it's transfer to the ventilation air. Many ancillary subjects are also covered.

The bibliography is grouped into nine themes, in each of which the papers or books are arranged chronologically. There is some overlap between the themes, particularly the first three, and the appropriate category of each paper is not always clear. The themes are:

1. Theory of heat flow
2. Measurement of heat flow in mines
3. Computer modelling and calculation of heat flow in mines
4. Rock thermal properties
5. Psychrometry and enthalpy
6. Ventilation computer modelling
7. Design of ventilation and cooling systems
8. Strength of ice-rock mixtures
9. Related miscellaneous topics

Most of the heat flow literature related to mines derives from the overheating problems in deep mines where the virgin rock temperature is high. Only one paper deals with the problem of cooling in a mine in permafrost (180). The major consideration in heat flow, at or near the freezing point, is the very large heat of fusion of ice as compared to the heat capacity of rock, ice or water. Psychrometry is included because of heat transfer to or from the ventilating air.

In hot mines the extent of evaporation of water from roadway surfaces is a major consideration in calculating results and the description of wetness is a major difficulty. In cold mines the vapour pressure of water is less and the effect on heat transfer calculations is generally much less significant. Thus the formulation of models is probably less complex. Possibly, the main significant point in evaporation or sublimation of water into the ventilating air would be in removing the heat released during freezing of tailings underground. In this process the saturation of air at the freezing temperature would remove about the same amount of heat as dry air 10 °C cooler.

There is a substantial body of literature relating to permafrost generally produced mainly in the USSR, USA (Alaska) and Canada. Amongst this there have been a substantial number of papers on heat flow and the properties of frozen soil. The major objectives in these studies appear to be: first, the design of building and other engineering structures foundations in the presence of possibly catastrophic failure if thawing occurs; and second, the prediction and control of environmental changes following large structures such as roads and pipelines. Some of these have been included in this bibliography. However, the coverage is not exhaustive.

The finite element approach is expected to be useful in the modelling of the heat transfer in a real mining situation. It is hoped that the MRL expertise in rock mechanics modelling in mines can be applied to heat problems.

One very important design parameter in the heat flow problem is the design temperature of the frozen rock, as presumably, the creep and strength are temperature dependent. This is the rationale for including literature on strength of rock-ice mixtures.

INTRODUCTION

Le Canada possède de vastes étendues de pergélisol où les possibilités d'exploitation minière sont nombreuses. L'exploitation d'une mine dans le pergélisol comporte des problèmes particuliers touchant à la stabilité des excavations minières. Il s'avère souvent essentiel d'empêcher la glace de fondre dans les interstices de la roche. Le point de départ de cette bibliographie a été le désir d'un exploitant d'une mine dans le nord de congeler du remblai dans ses galeries pour ensuite exploiter les piliers adjacents. Cette bibliograhie porte sur les transferts de chaleur dans la roche et les eéchanges avec l'air de ventilation. Un grand nombre de sujets connexes sont aussi traités.

La bibliographie est articulée autour de neuf thèmes se chevauchent, notamment les trois premiers, et les categories ne sont clairement definies. Les themes sont:

1. la théorie des transferts de chaleur
2. la mesur des transferts de chaleur dans les mines
3. la simulation numérique et le calcul des transferts de chaleur dans les mines
4. les propriétés thermiques des roches
5. la simulation numérique de la ventilation
6. la conception des systèmes de ventilation et de climatisation dans les mines
7. la résistance des mélanges roche-glace
8. sujets connexes divers

La plupart des ouvrages sur les transferts de chaleur dans les secteur minier portent sur les problèmes de surchauffe dans les mines profondes où la température de la roche vierge est élevée. Un seul ouvrage porte sur le probème de la climatisation dans une mine creusée dans le pergélisol (180). Le principal facteur de transfert de chaleur à considérer au voisinage du point de congélation est la très grande chaleur de fusion de la glace par rapport à la chaleur spécifique de la roche, de la glace ou de l'eau. La psychrométrie est abordée à cause des transferts de chaleur par ou vers l'air.

Dans les mines chaudes, l'évaporation d'eau par les surfaces des voies de roulement est important dans le calcul des résultats, et la description du niveau d'humidité est problématique. Dans les mines froides, la pression de vapeur d'eau est moindre, et l'effet sur les calcul de transfert de chaleurt est en général beaucoup moins important. Ainsi, la formulation de modèles est probablement moins complexe. Il est possible que l'évaporation ou la sublimation d'eau dans l'air de ventilation serve surtout à éliminer la chaleur liberée pendant le gel des résidus dans le sous-sol. En cours de route, à cause de la saturation de l'air au point de congélation, la meme quantité de chaleur est extraite sous forme d'air sec à -10 °C.

Beaucoup d'ouvrages ont été publiés sur le pergélisol, sut rtout en URSS, aux E.-U. (Alaska) et au Canada, dont un grand nombre sur les transferts de chaleur et les propriétés du sol gelé. Les principaux objectifs de ces études semblent être: premièrement, la conception de fondations d'immeubles et d'autres ouvrages de génie là où un dégel porrait être catastrophique; et deuxièmement, la prévision et le contrôle des changements environnementaux après la construction de grands ouvrages, tels des routes ou des pipelines. certaines de ces publications sont incluses dans cette bibliographie qui n'est toutefois pas exhaustive.

La méthodes des éléments finis devrait être utile pour modéliser les transferts de chaleur dans une vraie mine. Il est à espérer que les compétences des LRM en modélisation de la mécanique des roche dans les mines peuvent être mises à profit dans le problèmes chaleur.

Un paramètre de conception très important dans les problèm des transferts de chaleur est la température théorique de la roche gelée cale fluage et la résistance serait fonction de la température. Voilà pourquoi nous incluons des ouvrages sur la résistance des mélanges roche-glace.

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