Material Instability Hazards in Mine-Processing Operations

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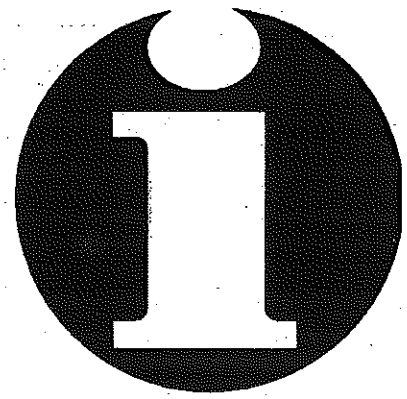

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ABSTRACT

Many accidents occur in the mining industry as a result of the instability of material during handling and processing operations. Accidents due to dump point instability at stockpiles, and at spoil or waste piles, for example, occur with alarming frequency. Miners must be trained to be better aware of these hazards. Information on safe working procedures at stockpiles and surge piles is provided. Mine operators must review their training and operating procedures regularly to ensure that hazardous conditions are avoided.

INTRODUCTION

An integral part of the mining process is the handling and storage of large volumes of material. Raw product must be temporarily stored to provide a steady flow of material for processing; processed material must be temporarily stored to provide sufficient supply to meet fluctuating customer demand. Waste products must be handled and permanently disposed of.

In performing these activities, miners are dealing with material in a loose condition, and often operating heavy equipment directly on such material. The instability of this material, and the lack of appreciation for the potential hazards, has been a major cause of accidents in the mining industry.

This report will review the types of accidents which occur, due to material instability, at processing facilities. The causes of these accidents can usually be traced to operating procedures which do not adequately take into account the behavior of loose material, and place too much reliance on the strength of such material. Material handling and storage procedures must be examined to ensure that workers are not placed in potentially dangerous situations.

REVIEW OF ACCIDENT INFORMATION

The Mine Safety and Health Administration maintains information on the accidents reported by the mining industry. A general review of this information, over the five year period through 1992, indicates that 150 accidents were reported that were directly attributable to the instability of material in handling and processing operations. Another 36 accidents were attributed to "overtravel" of equipment at a dump point, but instability of the dump point area may have been a factor in many of these cases.

A breakdown of these accidents is shown in Table 1. An attempt was made to include only those reported accidents which involved instability of material

as it was being disposed of, handled, or processed. Cases involving highwall or face instability are not included. These numbers include all reported incidents, even those where no injury may have resulted. As indicated, fatalities did occur in 28 of the 186 listed accidents.

Stockpile or ore pile dump point instability	48/7
Waste or spoil pile dump point instability	28/1
"Overtravel" at dump point	36/6
Slide of material from above worker in bin, at pile, etc.	26/8
Slide onto loading equipment as material was being loaded from toe of pile	16/1
Collapse of bridged material beneath worker/ equipment at bin, surge pile, etc.	12/4
Collapse of edge of haulroad	20/1
Totals 186 accidents/28 fatalities	

Table 1 - Number of accidents/fatalities involving material instability.

It should be noted that this review of accident data was done to attempt to identify the main areas of concern and the main factors involved. The available information on contributing factors is often limited and some judgements have been made to arrive at the above categories.

As indicated by the accident data above, surge piles and stockpiles are areas of particular concern.

SURGE PILES

Surge piles vary in design, but have the common feature of feeding material onto a conveyor belt which runs in a tunnel beneath the pile. Typically there are a number of different draw-point openings which can be activated to discharge material from different parts of the pile.

When a feeder is activated, material slides through the opening onto the conveyor belt. Material flows through the opening from a cone-shaped zone above the draw point. The angle or steepness of the sides of the cone depends on the type and condition of the material. Factors such as moisture, amount of fines, how loose or compact the material is, and temperature, all affect the shape of the cone. A loose, granular material may form an angle of 35 to 45 degrees, while a material with a higher moisture and fines content, which is compacted, will stand at angles of 65 degrees, or steeper.

At many mines the storage or discharge capacity of a surge pile has been increased by using mobile equipment, operating directly on the pile, to push material to the draw points. This practice exposes the equipment operator to potentially hazardous conditions because the stockpile material itself is being relied on to support the equipment working on the pile.

There are a number of dangers associated with the operation of a surge pile. Four situations are of particular concern.

First, it is obviously extremely dangerous for a person or piece of equipment to be on the pile above the draw-off point when a feeder is activated. Once the material begins to feed into the draw-off, the flowing material will not support any weight. When flowing into a draw point, material has been described as "quicksand." A person or piece of equipment which is near a feeder when the feeder is activated will be drawn into the material with disastrous results.

The second danger deals with the safety of working near the edge of the cone of discharging material. While being on the material which is flowing into the feeder is obviously dangerous, because such material will not support weight, the material around the edge of the cone is also dangerous. This material is only marginally stable and is normally on the verge of flowing. It has just enough strength to hold up its own weight, and will not necessarily support the additional weight of a piece of equipment, or even a person. No one should walk near the edge of a withdrawal cone, and equipment operators must be extremely careful to avoid getting to a point where the weight of their equipment may collapse the edge of the cone. If this occurs the equipment will be drawn into the draw hole and may become buried.

The third condition may be the most dangerous. In this case, a completely hidden danger can occur when material bridges or arches over the draw point, creating a void just above the discharge opening. The stability of this bridge may be precarious, depending on the temporary strength of a frozen crust of material, or resulting from a compacted zone which may gradually spall away and collapse. A bridge of material may support its own weight, but may suddenly collapse without warning under the weight of equipment or personnel. Surge pile accidents have most commonly occurred when a dozer has driven over and collapsed a bridged area (fig. 1).

The practice of operating mobile equipment directly on a stockpile can contribute to bridging problems by adversely affecting how well the material flows to the draw point. The weight and the vibration of the equipment as it operates on a pile tends to pack the material below it. The tighter packed material has less of a tendency to flow freely. A bridge can form because the deeper material, i.e. the material directly above the feeder, is in a looser condition and more readily flows while the denser material nearer the surface of the pile arches over the opening. Denser packing may also result from material dropping on the pile from a conveyor, and/or from the weight of the material itself as the pile gets higher.

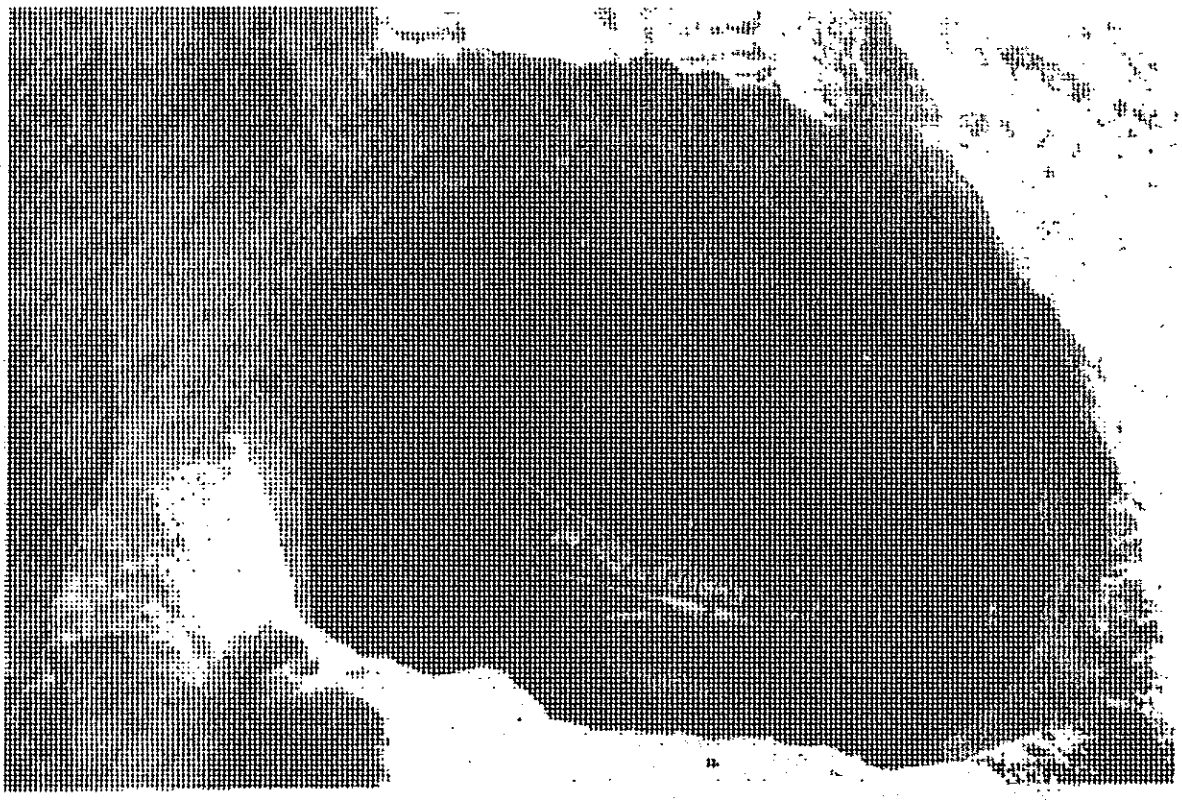

Figure 1 - Fatal accident from dozer falling into hidden void.

Bridging can occur due to freezing when ice bonds the near-surface material, giving it a high temporary strength, while the material buried deeper in the pile doesn't freeze and remains able to flow. The unfrozen material discharges through the draw point, while the frozen material arches over the void. As the material thaws, the temporary strength from freezing gradually is lost and the bridged area can collapse, endangering anyone on the pile.

Bridging may also be influenced by the percentage of fines in the material and by its moisture content. The presence of moist fines can result in the creation of surface tension which makes the stockpile material adhere or tend to cake, and makes it less free flowing.

A bridge of material over a void is an extremely dangerous condition. On the surface of the pile, there may be no physical indication that the void exists. Once a bridge has developed, it can collapse at any time from loss of strength due to vibration, thawing, or gradual spalling from underneath, or it may fail due to the added weight of equipment or a person.

The fourth dangerous situation occurs when a feeder becomes clogged. The concern is that the efforts to get the material flowing again may expose miners to hazardous conditions from unstable material above them, or from the flowing material once the obstruction is freed. Fatalities have occurred when attempts have been made, from on top of the pile, above a bridged opening, to break through or weaken material which was known, or suspected, to have bridged. In these cases, the stockpiled material which the workers are trying to free, is also the material which is providing support for the people involved. This practice invites disaster and must not be permitted.

To avoid placing miners in danger from the different situations described above, a surge-pile-safety program must be followed. Such a program must cover a number of points, as described in the following.

1. TRAINING - Perhaps the most important part of a surge-pile-safety-program is training. Everyone who works on or near surge piles must be trained to be aware of the dangers. They must understand how the pile works and the significance of the cone of material immediately above the feeder. This includes the miners who work around the pile, as well as others, such as engineers, contractors, and suppliers who may have reason to be on or near the pile.

2. WORK METHODS - Workers must stay away from the cone area and realize that its size depends on the height of the pile and the condition (draw angle) of the material. Workers should assume there is a hidden void over each feeder because one can develop any time that a feeder might be activated.

Equipment operators need to be specifically trained on pushing material toward the draw-point. This is of particular concern because of the limited field of view from the cab.

With the danger of collapse of the edge of the draw hole, material should not be pushed directly into the draw hole. Material should be bumped in with other material, so that the equipment can stay a safe distance from the edge. Equipment should always be operated perpendicular to the edge of the draw hole. As the use of remotely controlled equipment becomes more common, moving material on surge piles is one activity where the use of such equipment could be particularly beneficial.

3. FEEDER LOCATION INDICATORS - The location of each feeder should be identified by a marker. This will give workers an indication of the areas of the pile which must be avoided.

4. ACTIVE FEEDER INDICATORS - Activated feeders should be identified by a blinking light or some other readily observed method. This will allow equipment operators to be alert to feeding material, and to the possible development of a void above a discharge point.

5. COMMUNICATIONS - Many of the potential problems can be eliminated by having proper communications between the persons who work on or near the pile and the persons controlling the feeders. Everyone involved should know which feeders are being used, and who is working on the pile. Before starting a feeder, operators must be certain by visual inspection, or other positive means, that no one will be endangered. Mobile equipment operators who work directly on the pile should be required to verbally communicate with an assigned person on a regular time cycle.

6. FULLY ENCLOSED CAB - Any equipment that operates on a surge pile should be equipped with a fully enclosed cab which is supplied with breathing apparatus. Cabs equipped with strong window mountings and high-strength window material, or window guards, would maintain their integrity in the event the piece of equipment became buried. In this regard, mine operators and equipment manufacturers should explore, develop and implement measures to improve cab window integrity.

7. ADEQUATE LIGHTING - At many mines, stockpiling operations are performed at night. Night operations raise new concerns because of the reduced visibility. For nighttime activities, the work area must be adequately illuminated so that the operators perceptions and judgements are not adversely affected.

8. LOCKOUT REQUIREMENTS - Any repair work should be performed when the facility is emptied and there is no hazard from unstable material either above or below the work area. If there is a need to go near a feeder which has not been emptied, only workers specifically trained for the dangers should be used, feeders should be shut off and locked-out, the status of the feeder just before it was locked out, i.e. either flowing or blocked, should be known and taken into account, and a safety harness and line, with a second person keeping the line taut should be used.

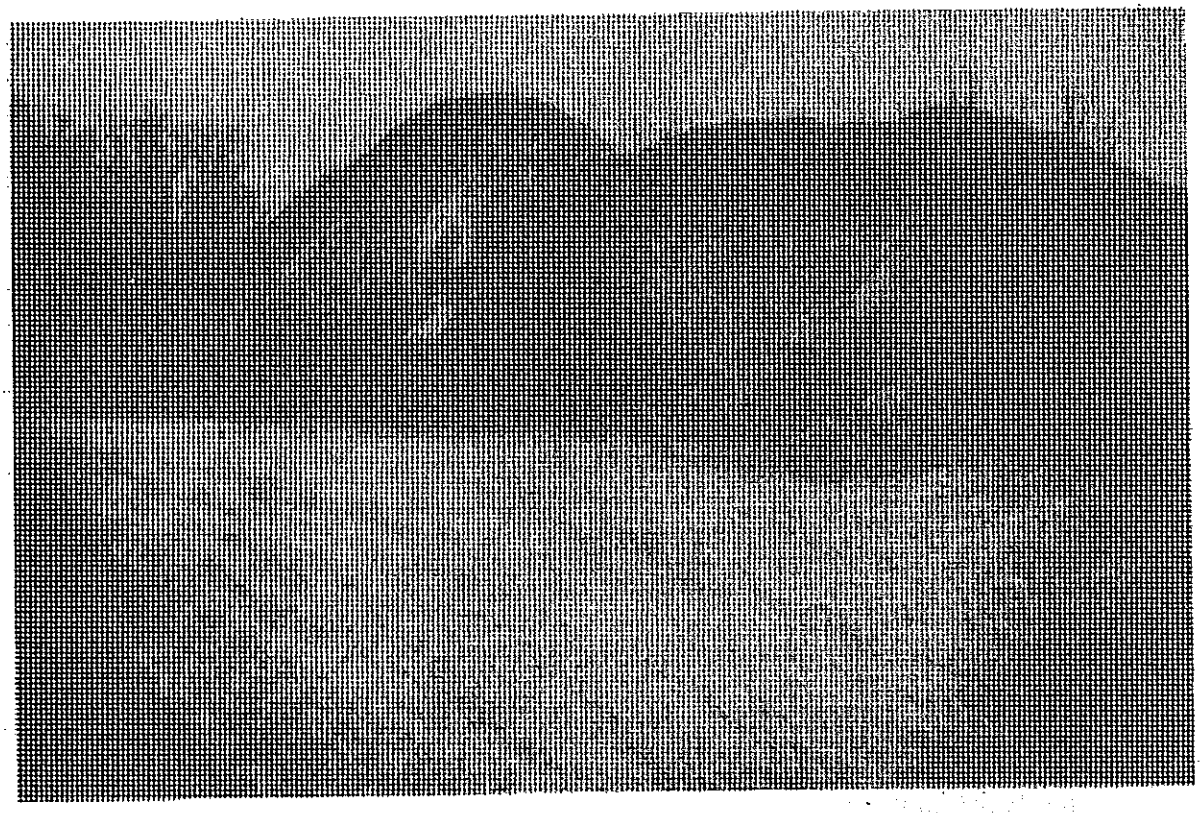

Figure 2 - Accident from collapse of stockpile edge.

6. Equipment operators may get a false sense of security from the presence of a berm. The presence of a berm does not necessarily indicate that it is safe to back to the berm and dump. The berm may have been undercut on the other side from the load-out operation. Also, depending on the conditions, it may not be safe from the standpoint of the amount of load on the slope, especially for the larger capacity haul trucks, to back all the way to the berm. Larger trucks may need to stop short of the berm and dump farther back from the edge of the slope so that the significant weight that they add does not cause the slope to fail.

When material is loaded out from the toe of a stockpile, the slope is steepened in that area. This weakens the slope, making it less stable and more prone to slide. As an equipment operator removes more material, the point can be reached where a collapse of the side of the pile can endanger the operator or anyone working near the toe of the pile. As previously mentioned, this oversteepening also poses a serious threat to equipment that may operate near the edge of the slope on top of the pile.

Loader operators, and others who may work in the area, need to appreciate the potential dangers created by removing material from the toe of a pile, and need to follow safe work practices.

1. The height of material that has been oversteepened should be limited so that a collapse of the slope will not endanger the loader operator.

2. A good safety rule is that a loader should not work into the toe of a bank which is higher than the reach of the equipment. In Canada, there is a regulation that the height of a steep working face in unconsolidated material shall not be more than 2.0 meters above the reach of the loading equipment. With this limitation, the quantity of material which could be involved in a slide is restricted, and the operator is able to safely trim down steep or overhanging material.

3. When a portion of the slope has been oversteepened from being loaded out, material should be pushed down from the top of the pile, using track-mounted equipment, to flatten the slope at least back to it's angle of repose.

4. When working near the toe of the pile, the operator should keep the piece of equipment nearly perpendicular to the slope. This helps keep the operator's compartment back away from any potential slides.

5. Digging into frozen material can be dangerous because the ice binds the material and allows it to stand at steep slopes, or to form overhangs. As thawing occurs the material can collapse without warning. Operators should be aware of this potential hazard.

6. The activities of dumping additional material on a pile, and reclaiming material from the toe of the pile, need to be coordinated so that equipment is not working on top of the pile near an area where

material is being loaded out, or has been loaded out, from the toe of the slope.

SPOIL AND WASTE PILES

Problems can occur when the method of disposal of spoil or waste is to dump the material directly over the edge of a pile. This situation is the same as the cases described above for the truck-built stockpiles. Normally there is less concern for a stability problem at a waste pile because the pile is not loaded out at the toe and steepened. However, the same concern applies, that is, that the edge area of the pile must be capable of supporting the truck weight.

The stability of the edge is a concern in these situations for two main reasons. First, material such as spoil tends to be variable in nature. As a result of the end-dumping operation, zones of finer material can be created which may be significantly weaker than the average material. This possibility can be increased by the tendency for particle-size segregation which naturally occurs from end-dumping. Problems can occur when a weak zone develops at the dump point.

The second reason for concern is that larger and larger capacity trucks are being used in these situations. A dump point which may be stable for a 35-ton truck, may not be stable when loaded with an 70-ton truck. With the larger trucks, it is especially important that the materials involved and the dump procedures be analyzed to ensure that the factors of safety for support of the truck are adequate. Based on the size of truck being used and the properties of the dump material, engineering analyses can be performed to indicate how close to the edge of the slope the truck can come, while maintaining an adequate factor of safety against slope failure.

OTHER STABILITY RELATED PROBLEMS

In processing operations, the stability of the materials are also a concern at bins and hoppers, and haulroad fills. Accidents involving workers getting trapped in material inside bins and hoppers, while attempting to free blockages or clean down material, continues to be a significant problem in the mining industry. Companies need to regularly review their procedures and provide training to their workers so that hazardous conditions and practices are avoided.

The design and condition of haulage roads has a significant impact on both the safety and efficiency of a mining operation. The stability of haulroad fills is a concern as indicated by the 20 reported accidents, in the five year period up to 1992, caused by failure of the haulroad as equipment was traveling by. Haulroad fills must be properly engineered if they are to be relied on to support the haulage equipment. Key factors related to fill stability are:

- removal of vegetation and weak, unsuitable foundation material,

- construction of the fill in horizontal lifts which are benched or keyed into the slope,

- adequate compaction of the fill in thin lifts,

- outslopes which are not too steep for the strength of the material, and provide an adequate factor of safety against slope instability, with the weight of haulage equipment included,

- sufficient fill width so that the berm is constructed on the compacted, horizontal road base, rather than by piling loose material over the outslope, and

- adequate provisions for drainage, particularly the diversion of surface runoff.

SUMMARY

If the goal of zero mining fatalities by the year 2000 is to be possible, progress must be made on accidents related to the instability of material in mine-processing operations. The keys appear to be to provide training to miners so that they understand and appreciate the hazards involved, and to regularly review material handling procedures to ensure that hazardous situations are avoided. The information provided in this paper should assist mine operators in achieving these goals.