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Analysis of Safety Aspects And Mining Practices For Effective Ground Control in Surface Mining

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ABSTRACT

Fatalities caused by highwall/spoilbank failure in the surface mines, coal and non-metal, increased to an alarming rate of seven during 1999. To determine the causes of slope failure and successful mining practices, the National Institute for Occupational Health and Safety undertook a study. The study included:

1. A review of accident statistics;
2. A review of Federal and state mining laws pertaining to surface mining;
3. A literature review, and;
4. Mine visits.

The study emphasized surface mines in the states of West Virginia, Ohio, and Pennsylvania.

The review of a decade's accident statistics using the Mine Safety and Health Administration's (MSHA) database showed that approximately 40% of all ground control related incidents reported to MSHA occurred in just four eastern states: Kentucky, West Virginia, Pennsylvania, and Ohio. The comprehensive literature search provided a historical perspective of highwall stability issues. Eleven mines were visited to obtain data on their mining practice or design. Commodities included coal, sandstone, and limestone. Based on the visits, five case studies were developed to represent typical mining methods and effective ground control practices used in eastern surface mines. Benching was found to be a common technique to reduce the overall highwall slope angle. Decking in the softer zones, such as shale, proved useful in controlling damage due to blasting.

INTRODUCTION

In recent years, highwall/spoilbank failures in the surface mines have resulted in significant loss to human lives, property, and production. A highwall is always changing as the process of extracting coal or ore continues. The challenge, therefore, is to maintain a stable highwall throughout the mine's operating life. A stable highwall requires an optimum slope under given conditions. Effective slope design includes determining safe and workable bench height, bench face angle , and bench width.

To determine the relationship of mine design parameters/practices and effective ground control in surface mining, this study was undertaken. It included coal and nonmetal mines, and consisted of four parts:

- A review of accident statistics for the 1988-1997 period and Mine Safety and Health Administration's (MSHA) accident investigation reports for the 1996-1999 period;
- A review of pertinent Federal mining laws and the State laws of Pennsylvania, West Virginia, and Ohio;
- A comprehensive review of relevant published literature over the past decade; and
- Visits to eleven operating surface mines representative of the tri-state area.

The mining laws, both Federal and state, guide the design of surface mines; significant regulations are summarized in Appendix A.

The data obtained from the mine visits was utilized to prepare five case studies to show the area's different geological settings, operating parameters, and effective ground control practices under existing conditions.

The knowledge gained from this research will enable better mine planning so that the health and safety of the surface mine worker can be improved.

ACKNOWLEDGMENTS

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ACCIDENT ANALYSIS

Period 1988 - 1997

Highwall accident statistics from the MSHA data base were analyzed for the ten-year period for incident frequency, degree of injury, nature of injury, equipment involved, coal and non-metal breakdown, worker activity at the time of accident, and other relevant parameters. Salient results of the analysis are presented below.

In all, there were 428 accidents caused by the highwall instability in active coal and non-metal mines. Four mines had four incidents each, 13 mines had 3, 35 mines had 2, and the remaining 303 mines had one highwall incident. Thus, a total of 355 mines reported 428 incidents during the period. Mines with multiple incidences, three and four, are listed in Appendix B. For each mine, number of incidents, year of occurrence, failure type (highwall/spoilbank), degree of injury, and the commodity mined are provided. The table 1 shows the breakdown of all accidents by degree of injury:

Table 1. Accidents by degree of injury

Degree category (definition)	Occurrence, %
0 (No injury)	5.0
1 (Fatal)	7.0
2 (Permanent disability)	0.0
3 (Days away from work)	57.0
4 (Days away and restricted activity)	5.0
5 (Days of restricted activity)	4.0
6 (No days lost)	22.0
Total	100.0

Of the 28 fatal accidents, the majority (70%) occurred in non-metal mines. This represents approximately three fatal accidents per year over the 10-year period. Considering all accident incidents (428), the distribution between coal and nonmetal mines is about 50-50. On worker exposure basis, the incidence rate at surface coal mines is about twice that at surface nonmetal mines. Refer to the section on surface mine worker population.

The 428 accidents were categorized by the nature of injury caused and are as follows (table 2):

Table 2. Accidents by nature of injury

Nature of injury	Occurrence, %
Contusions, bruises	23.0
Multiple injuries	18.0
Cut, laceration, puncture	17.0
Sprain, strain	8.0
Others*	34.0
Total	100.0

*Has over 30 injury classifications.

Approximately 26% of all accidents caused by highwall failure involved heavy earth moving equipment, such as the drill, front-end loader, dozer, shovel/dragline, and trucks. Approximately half of the injuries were caused when the failed material hit the victim directly. The remaining 24% involved miscellaneous equipment items (over 40). Figure 1 shows this breakdown.

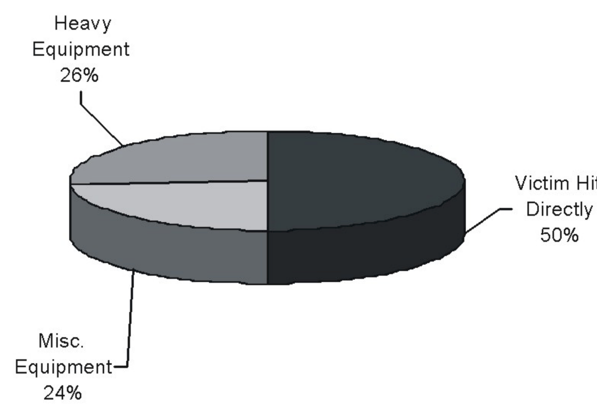

Figure 1. Accidents by worker involvement

Handling supplies or material was found to be the single most frequent (11%) worker activity when injured, followed by idle category (7%). Handling explosives, drilling face, and surface equipment (not elsewhere classified) each represent about 6% of all accidents (18% total). The remaining 64% are distributed over 80 mine worker activities. Figure 2 shows this breakdown.

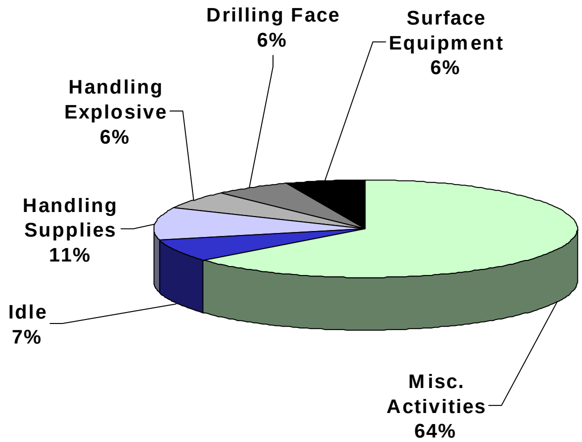

Figure 2. Accidents by worker activity

Four eastern states, Kentucky, West Virginia, Pennsylvania, and Ohio, experienced some 40% of all highwall incidents during the study period.

Accident narratives do not provide accurate information on the size of rock falls. It can generally be estimated that about 50% of highwall instability incidents are caused by falling of small rocks or fragments.

A review of months of incident occurrence does not provide a significant correlation. In other words, winter months were not significantly accident prone due to freeze-thaw cycles.

Current Data

MSHA's Fatalgrams and accident investigation reports were reviewed for fatalities in 1998 and 1999. In 1998, there was one highwall failure accident in a coal operation. In 1999, there were seven fatalities, four in coal and three in non-metal mines. This is over two-fold increase compared to the average of approximately three fatalities per year during the ten-year study period. Salient findings/data for the eight accidents are presented below.

Two accidents were caused when spoilbank collapsed, the remaining six resulted due to falling rock from the highwall of active mining operations. In three cases, failed highwall material directly hit the victim; whereas, workers were operating equipment in the remaining situations. The equipment involved in the accidents include highwall drill, excavator (shovel), and truck. The occupation of workers included all phases of operations, i.e., truck driver, drill operator, excavator/shovel operator, and a company owner.

The size of rock falls varied between unspecified amount to massive or extremely large. Some reports mentioned the size as one kilogram, one tonne, and several tonnes.

Best practices, recommended by MSHA, to avoid the accidents were given as:

- Examine and monitor highwall often.
- Follow ground control plan.
- Train miners to recognize hazardous highwall conditions.
- Scale-down or support the hazardous highwall areas.
- Keep drill and other mobile equipment operators away from highwall face or highwall hazards by positioning them in safe locations.
- Employ mining methods that will maintain wall, bank, and slope stability in places where persons work or travel.
- Provide adequate berms to prevent over-travel at dump locations.

MSHA's accident investigation reports for the 1996-1999 period were thoroughly analyzed. Twelve fatality reports are summarized in Appendix C. The table includes data such as the commodity mined, types of failure, accident description, worker activity at the time of accident, weather conditions, citations, victim's occupation, equipment involved, and the height of highwall.

SURFACE MINE WORKER POPULATION

Mine Injury and Worktime, Quarterly from MSHA provided approximate surface mine employment data for 1998:

Commodity	No. of workers
Coal (includes anthracite and contractors) .	36,350
Non-metal (includes stone and contractors)	68,300
Total	104,650

As can be seen from the above, over 104,000 workers are exposed to the hazards of highwall instability in the United States mining industry.

LITERATURE REVIEW

Literature review pertaining to slope stability is provided below in three categories.

Mine Planning and Design

Mining parameters in a surface mine are influenced by strata conditions and their subsequent design for actual mining process. The structural aspects of overburden and floor material play a significant role in the predictive behavior of rock masses in response to the mining operations, especially of highwall stability and the formation of spoil dumps (*1*), and therefore, the choice of mining parameters. These parameters include bench width, height, and slope angle.

Planning of open-pit mines on a business-risk basis (*2*) emphasizes that confidence for slope design should be categorized using the same fundamental approach as that adopted for resource definitions–such as proven and possible reserves. For example, a proven slope angle requires that the continuity of the stratigraphic and lithological units within the affected rock mass is confirmed in space from adequate intersections. A possible slope angle, whereas, corresponds to typical slope angles based on experience in similar rocks and along discontinuities. A risk balance between mineral resources and slope angle is needed for developing efficient mine plans.

Study of South Wales open-pit site (*3*) provides significant relationships between the slope design and structural geological factors. The geological parameters that are most relevant to rock slope stability are:

- The persistence, attitude, and nature of discontinuities within the rock mass.
- The shear strength characteristics both within the rock mass and along discontinuities.
- The rock density.
- The potential for build-up of water pressure in the rock mass and in tension cracks in rock slopes.

Bedding planes are the most common through-going discontinuities, followed by joints, in coal measure sequences. Transcurrent (strike-dip) faults, unless major, do not lead to slope instability. Open-pit designs should attempt to avoid the presence of adversely oriented structurally controlled discontinuities in the highwall.

Gregg River Mine (*4*) in Alberta, Canada, had two highwall slopes 160 and 219.5 m (525 and 720 ft) high excavated in a dipping strata in approximately the same lithologic and structural environment. In the earlier phase of mining, the highwall experienced instability. In the later phase, using flatter bench face angles, the slope did not experience any significant movements. It was found that 50° bench face angle prevented toppling failure. Also, horizontal drain holes in critical areas of slope were successful in keeping water away.

A slope stability analysis performed at the Beulah lignite mine (*5*) indicated that most failures were in spoil piles more than 27.4 m (90 ft) high. Circular arc failures mostly occurred when the spoil slope were too steep for the height. The study recommended decreasing the pit width and lowering the overall slope angle by use of a spoil bench.

Mining Practice

Controlled blasting methods are commonly used in Australian mines (*6*) to maintain pit wall stability. The methods include cushion blasting, pre-splitting, post-splitting, and using them with production blasts. Pre-splitting requires a row of closely spaced blast holes drilled along the design excavation limit, charged very lightly and detonated simultaneously before the blast holes in front of them. It gives better results than post-splitting but is costly. It is suitable for situations where rock strength is moderate to very high with few joints. The desired results after excavation is a clean face with the hole traces visible on the final wall. Cushion blasting is the simplest and least expensive smooth wall blasting technique. It requires the back row holes lightly charged and are delayed sequentially and detonated after the more heavily charged production hole in the front. Post-split or trim blast consists of a row of parallel, closely spaced blast holes drilled along the pit limit. The holes are charged lightly and fired after the production blast holes have detonated.

In the United States, poor highwall stability is contributed partly by faulty blasting practices (*7*). In these cases, the explosive energy not only fractures the rock to be excavated but also the rock that borders the excavation.

Operating costs in open-pit mines (*8*) are a function of pit-wall angle. As the pit-wall is steepened, less waste rock has to be mined which results in reduced blasting, excavation, and transportation requirements. In addition, there are dewatering costs that include engineering design, installation of horizontal drains or wells, pumping, and water treatment. A decision analysis framework was used to assess the economic benefit of pit-wall depressurization in open-pit mines. The framework can be used to evaluate each proposed pit-wall configuration and dewatering system design and identify the optimum alternative.

Effective mountaintop removal operations in West Virginia (*9*) require sound engineering practices. The mining begins by clearing the trees from the permitted area so that wood is not commingled with the waste. A contour cut is then made on the lowest mineable seam. This mining provides control drainage and a bench to prevent the downslope placement of material. This is done with a large front-end loader and end-dump trucks haul overburden to a valley fill. After the contour cut is completed and appropriate drainage is in place, pre-stripping for the dragline begins.

Examination and Monitoring

The need for predicting movements of large-scale slope failure is great considering the operation hazards related to the displacement. The focus of this study (*10*) was to predict future displacement. Fourteen slope failures that progressed to partial or total collapse were reviewed. Monitoring of instability in coal and non-coal mines in South America was accomplished through the use of both wire extensometers and EDM prism surveying at the surface. In a Colombian coal mine, although total collapse of the slope did not develop, a greatly accelerated movement of 20.4 m (67 ft) did occur over a four-hour period. The slope failure involved sliding along non-daylighted, clay-shale bedding surfaces to a depth of 10.1 m (33 ft). Bedding and slope angle varied from 18 to 22° in the 121.9 m (400 ft) high footwall slope.

Middelburg Mine, South Africa, has been experiencing highwall stability problems. The highwalls at this mine are vertical, between 15.2 to 35.4 m (50 to 116 ft) high and are normally aligned to suit lease boundaries. The problems include potential toppling failure against the pre-split line and plane failure along joints in the rock mass. The mine management (*11*) has developed a rating system to identify and demarcate the problem areas. Some of the aspects covered include:

- Bench height – higher benches being higher risk.
- Work still to be done – subsequent blasting and loading of two seams and partings being high risk; low risk if not much work needed.
- Presence of water.
- Presence of potential plane or wedge failures.
- Overhang or poor pre-split problems on the highwall.

Microseismic monitoring of a slope failure was attempted at the Cardinal River open-pit mine in Alberta, Canada, in the mid-eighties (*12*). The project was not fully successful, but pointed out problems associated with microseismic procedures applicable to steep coal seams and geologically disturbed surroundings.

Eagle Butte Mine in Wyoming provides numerous challenges from geotechnical stand-point as the coal seam is 33.5 m (110 ft) thick, and overburden and interburden are weak with underclay at the mine site. In addition, a major sand channel complicates the stability conditions. Successful extraction of coal at this mine is contingent upon having a sound geotechnical mine plan and an effective slope monitoring program. A suite of field techniques have been employed in geotechnically sensitive areas which include surveying displacements, graphing displacements against time, field inspections, and setting stakes along displacement cracks (*13*).

Surveying methods have found widespread use as a means of monitoring wall stability in Australian open-pit mines (*14*). These methods include regular visual inspection on foot, in areas of concern; go/no-go switches across a crack; posts placed on either side of movement zones with measurement by a vernier calliper or tape; surveying methods including angular intersection and electronic distance measurements, and borehole extensometers with a depth gauge or displacement transducer. Other methods that may find use include:

- Terrestrial photogrammatic methods.
- Inclinometers.
- Global positioning systems.
- Radar.
- Time domain reflectrometry.

MINE VISITS

Eleven coal and non-metal mines were selected for mine visits. The purpose of the visits was to obtain relevant information form mine managers/engineers who are involved in the design of surface mines and highwall stability. The mines were selected based on parameters to include the distribution and frequency of highwall accidents, geography, geology, material mined, management, mining method, and equipment employed.

In addition to gathering information from the mine personnel, an operating surface mine was visited at each location. The mine visits covered parts of West Virginia, Pennsylvania, and Ohio. Materials mined include coal (anthracite and bituminous), limestone, and sandstone. Of the eleven mines, eight are coal, two limestone, and one sandstone. Figure 3 shows the general location of these mines in the eastern United States. Five case studies are provided to represent the mining practices and safety aspects of the study area. Typically, a case study addresses the geological setting and operational parameters (bench width, height, and slope angle) in a mining area for effective ground control. Figure 4 shows the geological settings and operational parameters for the five case studies.

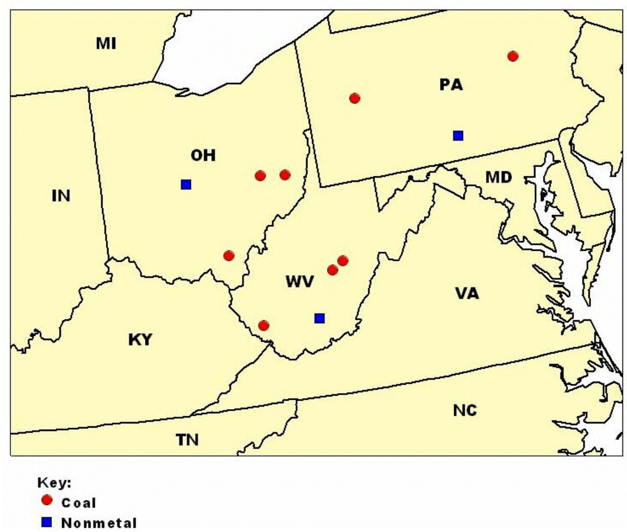

Figure 3. General mine location map

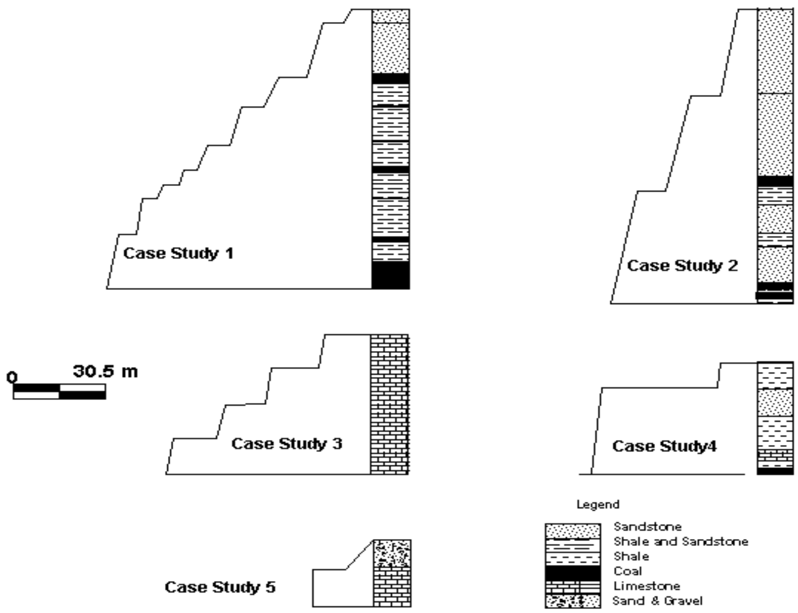

Figure 4. Geological settings and operational parameters

This study was limited to a small mining region with generally good geologic/mining conditions. Complex slope stability problems, therefore, were not encountered. Additional mines throughout the united States may need to be studied for answers to difficult ground control issues.

Case Study 1– Coal, Mountaintop Removal

Five coal seams are mined in benches (up to 9), two being the main seams each with about 2.7 m (9 ft) thick coal and separated by approximately 77.7 m (255 ft) of interburden. The overburden over the upper seam is about 29 m (95 ft), massive sandstone. The interburden mostly consists of sandstone and shale with bands of clay, and number of coal seams. The strata is almost horizontal and can be considered strong (good rating for stability purposes). The benches are 15.2 m (50 ft) high and plus 4.6 m (15 ft) wide. Highwalls in the area typically average 30.5 m (100 ft) and are about 15° off vertical. Haul roads are 30.5 m (100 ft) wide with maximum grade of 10%. Berms are maintained at 1.2 m (4 ft) or truck axle height.

Highwalls are visually examined three or four times per shift. Smaller charges and more decks are used in softer zones (shale and clay) for controlled breakage within and outside blasting area. Scaling is done using dozers, end loaders, shovels, and dragline.

Case Study 2–Coal, Mountaintop Removal and Contour

Two coal seams are mined in three benches, the upper seam coal being of 2.4 m (8 ft) thick and the lower one about 1.8 m (6 ft). Both seams are separated by approximately 41.1 m (135 ft). Overburden over the upper seam is massive sandstone, 71.6 m (235 ft) thick. The interburden between the seams is mainly sandstone with bands of clay, shale, and a number of coal seams. The strata is almost horizontal and can be considered strong (good rating for stability purposes). The benches are 30.5 m (100 ft) high and 9.1 m (30 ft) wide. typically, highwalls are approximately 30.5 m (100 ft) high. They, however, reach up to 106.7 m (350 ft) in places. The highwalls are nearly vertical (off 10°). Haul roads are 38.1 m (125 ft) wide with berms maintained at truck axle height. Pre-splitting is done by blasting a row of holes before production shots.

Highwalls are visually examined three or four times per shift. During adverse weather conditions (snow and rain), the spoilbanks are carefully examined. Attempt is made at all times to compact the spoil material to safe angle (<50°). Scaling is done using dozers and backhoe.

Case Study 3–Limestone, Benching

The overburden over a limestone deposit consists of soil and loose limestone rock, about 19.8 m (65 ft) thick. The limestone bed lies vertically and is mined for approximately 61 m (200 ft) in depth. The general areas has minor faults and folds, and the mineral bed can be considered strong (good rating for stability purposes).

Mining is done in four benches, 15.2 m (50 ft) high by 15.2 m (50 ft) wide each, keeping highwalls nearly (8° off) vertical. The maximum highwall height in this case is 15.2 m (50 ft). Haul roads are about 18.3 m (60 ft) wide with berms maintained at somewhat more than the truck axle height. Highwalls are visually examined three times per shift. Hazards are removed when they pose danger to workers or equipment. Scaling is done with a hydraulic excavator.

Case Study 4–Coal, Area Stripping

The overburden over a 1.2-m (4-ft) coal seam is 49.1 m (161 ft) thick, comprising of claystone, shale, sandstone, limestone, and shaley sandstone. Majority of the geologic column (39.6 m (130 ft)) can be divided into two groups–18.3 m (60 ft) sandstone and 21.3 m (70 ft) shale. The strata is horizontal and can be considered strong (good rating for stability purposes).

Highwalls in the area average 38.1 m (125 ft) high, nearly 6° off vertical. Typically, two separate lanes (plus 12.2 m (40 ft) wide each) are used for hauling material, one for empty and the other for loaded trucks. Berms are maintained at 1.8 m (6 ft) (plus truck axle height). Highwalls are visually examined three times per shift. Visual indicators (cracks, overhangs) trigger more intensive scaling efforts. Also, frequency of inspection increases to four times per shift during adverse weather (snow and rain) conditions. By continued experimentation, the current blasting design is arrived at to provide smooth/clean highwalls. Scaling is done by a dragline.

Case Study 5–Limestone, Contour (Open-pit)

The overburden over a 16.5-m (54-ft) limestone deposit is soil, sand, and gravel, about 12.2 m (40 ft) thick, most of which was mined earlier. The limestone bed is horizontal and massive, and can be considered very strong (excellent rating for stability purposes).

Mining is done in one bench, 16.5 m (54 ft) high by 12.2 m (40 ft) wide, keeping highwalls vertical. The maximum highwall height in this case is 16.5 m (54 ft). Haul roads are about 24.4 m (80 ft) wide with berms maintained at truck axle height. Pre-splitting is done by blasting a row of holes prior to production shots. Highwalls are examined visually each shift. Any cracks and loose material that have potential for failure are corrected immediately. Scaling is done using end loaders and backhoes. Blasting pattern was carefully designed to minimize damage to the nearby structures.
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CONCLUSIONS

- Considering all accident incidences, the distribution between coal and nonmetal mines is about 50-50. On worker exposure basis, the incidence rate at surface coal mines is about twice that at surface nonmetal mines.

- In half the incidents, the workers get injured when the failed highwall material hits them directly. Workers in all occupations are vulnerable to the highwall failure incidents.

- No single worker activity stands out to be the most accident prone. Just being at the pit, working or idle, puts the worker at risk.
- Approximately 50% of highwall accidents are caused by falling of small rocks or fragments.

- About 30-m (100-ft) highwalls can be maintained in stable conditions if the area strata is strong, such as massive sandstone. These highwalls are nearly vertical (off 5 to 15°) to vertical.

- Benching improves the stability of highwalls. The bench height normally does not exceed 15.2 m (50 ft) if the strata comprises of multiple coal seams, shale, sandstone, and limestone, making it somewhat weak.

- Pre-splitting in hard, massive rocks provides smooth highwall face, improving resource recovery without compromising highwall safety.

- Blasting pattern should be specifically designed for each mine site. Decking or small charges, in soft rock zones (shale and clay) minimizes damage to the highwall.

- Spoilbanks, at all times, should be kept compacted to a safe angle (less than 50°). Thorough visual examinations are needed in adverse weather (rain and snow) conditions.

- Berms along the haul roads and dump areas need to be maintained at more than the truck axle height, preferably by 0.3 m (1 ft).

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APPENDIX A.–FEDERAL AND STATE LAWS

Significant regulations pertaining to surface mine design are paraphrased in this appendix. For details and complete language, refer to particular stipulations in the relevant book.

FEDERAL REGULATIONS

Code of Federal Regulations, 30, Minerals Resources, stipulates regulations for coal and non-metal resources using surface mining methods. It provides guidance for mine design including ground control coal, crushed stone, and non-metal mines.

Coal

Part 77, subpart K provides regulations for coal and significant regulations are discussed below.

- Each operator shall establish and follow a ground control plan for the safe control of all highwalls, pits, and spoilbanks, which shall be consistent with prudent engineering design and insure safe working conditions. The mining methods employed by the operator shall be selected to insure highwall and spoilbank stability. A copy of such plan shall be filed with the appropriate coal mine health and safety district office.

- Loose hazardous material shall be stripped for a safe distance from the pit top or highwall and the loose unconsolidated material shall be sloped to the angle of repose or barriers, baffle boards, screens, or other devices be provided that afford equivalent protection.
- To insure safe operation, the width and height of benches shall be governed by type of equipment to be used and operation to be performed.

- Highwall banks, benches, and terrain sloping into the working areas shall be examined after each rain, freeze, or thaw before men work in such areas, and such examination shall be made and recorded. Overhanging highwalls and banks shall be taken down and other unsafe ground conditions shall be corrected promptly, or the area shall be posted.

- Hazardous areas shall be scaled before any other work is performed in the hazardous area. When scaling of highwalls is necessary to correct conditions that are hazardous to persons in the area, a safe means shall be provided for performing such work. Whenever it becomes necessary for safety to remove hazardous materials from highwalls by hand, the hazardous material shall be approached from a safe direction and the material removed from a safe location.

- Men, other than those necessary to correct unsafe conditions, shall not work near or under dangerous highwalls, and those involved in repair work shall take special safety precautions.

Non-Metal and Crushed Stone

Part 55.3 addresses ground control of non-metal mines and Part 56.3 covers crushed stone operations. Regulations for both are identical and include the above stipulations for coal. There are, however, a few additions as discussed below:

- Material, other than hanging material, to be broken by secondary drilling and blasting, shall be blocked to prevent hazardous movement before persons commence breaking and will work from a safe location, if the material movement occurs.

- A scaling bar of sufficient length shall be provided where manual scaling is required.

- When rock bolts are used for ground support, anchorage test procedures shall be established and tests will be conducted to determine the anchorage capacity of rock bolt installation.

STATE MINING LAWS

State mining laws for the three states that pertain to surface mine design including ground control are presented below.

Pennsylvania

For anthracite mines, while excavating, the spoilbanks and earth cuts shall be sloped no more than 45°. An examination shall be made at frequent intervals to determine if danger exists from slides or overhang and when such conditions present, they shall be immediately corrected. Chapter 77, Title 25 of the Pennsylvania Code deals with noncoal mining and pertinent regulations are discussed below.

- The maximum height of the working face of a bench in consolidated material may not exceed 15.2 m (50 ft), and that in unconsolidated material may not exceed 7.6 m (25 ft). A waiver may be granted for greater or lower working heights if geologic and safety considerations (stability analysis) so require. The minimum width for a horizontal bench between successive working faces shall be 7.6 m (25 ft).

- An operator shall provide a stability analysis when requesting a waiver for developing greater than 15.2 m (50 ft) face. The analysis shall include a stereo net analysis or equivalent for the working face strata. Man-made features within a distance equivalent to three times the maximum proposed depth of the pit measured from the maximum lateral extent of the final working face shall be identified.

- There are no specific regulations for surface mining of coal that pertain to slope stability.

West Virginia

Regulations for open-pit coal and limestone mines are identical and are provided in Title 56, Series 6 and 7, respectively, which originate from the Office of Miners' Health, Safety and Training. Significant stipulations are presented below.

- Highwall overburden shall be sloped to minimize slides and overhanging ledges and all loose material scaled.

- If the highwall shows evidence of movement, or appears to be weakened in anyway, the areas shall be made safe or abandoned and dangered off.

- Blasted material shall be loaded in such a manner as to minimize the danger of rock slides endangering workmen.

- Regulations for quarry operations are included in Title 56, Series 3. Significant stipulations are as follows, which are in addition to the above.

- When a bench is required to insure safe operations, its width and height shall be governed by the type of equipment to be used, the operations to be performed, type of material, and height of the walls.

- Spoilbanks shall be kept free of bodies of water and spoil material shall be sloped to the angle of repose or other measures taken to prevent the material from sliding into the pit.

Ohio

Ohio state mine safety laws do not have specific requirements pertaining to the highwall/slope stability in coal and non-metal surface mines.

APPENDIX B. HIGHWALL FAILURE- MINES WITH MULTIPLE INCIDENCES (MORE THAN TWO) 1988-1997

Line ref.	Mine, state	Year	Commodity mined	Highwall/spoilbank	Degree of injury	No. of incidences	Fatalities
1	Coal mine, AL	90,91,92,92	Coal	Highwall	3	4	
2	Coal mine, KY	90,91,91,92	Coal	1 Spoilbank, 3 Highwall	6,3,3,3	4	
3	Coal mine, PA	91,91,93,93	Coal	Highwall	1,3,3,0	4	One
4	Coal mine, WV	92,92,94,95	Coal	Highwall	6,3,3,3	4	
5	Coal mine, IL	89,91,92	Coal	Highwall	3,3,3	3	
6	Non-metal mine, KY	91,91,97	Stone	Highwall	4,3,5	3	
7	Non-metal mine, KY	90,90,95	Stone	Highwall	1,6,6	3	One
8	Coal mine, MT	93,94,94	Coal	Highwall	0,0,0	3	
9	Non-metal mine, PA	90,95,95	Slate	Highwall	6,3,3	3	
10	Non-metal mine, VT	92,94,96	Granite	Highwall	3,1,4	3	One
11	Coal mine, PA	88,89,90	Coal	Highwall	6,0,3	3	
12	Non-metal mine, VT	94,94,95	Slate	Highwall	3,3,3	3	
13	Non-metal mine, WA	95,95,95	Stone	Highwall	1,3,1	3	Two
14	Coal mine, WV	90,90,92	Coal	Highwall	3	3	
15	Coal mine, WV	93,94,94	Coal	Highwall	3,3,6	3	
16	Coal mine, WV	89,90,96	Coal	Highwall	1,6,3	3	One
17	Non-metal mine, MO	88,88,91	Stone	Highwall	6,6,3	3	

Source: Mine Safety and Health Administration

APPENDIX C.-- HIGHWALL FATALITIES 1996-1999.

Line ref.	Mine, state	Date	Commodity	Spoilbank/ Highwall	Msha category	Final highwall, ft	Overburden geology	Special features cited	Accident description	Rock volume	Weather	Citations issued	Occupation	Equipment involved
1	Non-metal Mine, AL	Oct-99	Limestone	Highwall	Fall of Highwall	110	Limestone		Splicing cable when rock fell, hit his head.	Small rocks		Failure to scale loose ground, to exam, test loose ground above work area.	Electrician	
2	Coal Mine, PA	May-99	Anthracite	Spoilbank	Fall of Highwall	130	Spoil-rock and dirt		Preparing to load truck when spoil pile collapsed on shovel.	Few tons		Failed to report, correct hazardous conditions, no benching approved in plan.	Shovel Operator	Shovel
3	Non-metal Mine, AL	Mar-99	Limestone	Highwall	Machinery	95		Clay seam in highwall	Removing mud seam when rock fell, hit equipment	2,700 lb	Clear, warm	Failed to exam highwall, failed to scale loose ground, failed to log exam record.	Excavator Operator	Excavator
4	Coal Mine, IN	Feb-99	coal	Highwall	Fall of Highwall	74	Shale, sandstone, 3 coal seams	Faults /fractures	Walking to highwall when rock fell, hit him.	7 cu yd	Cloudy, snow	Failed to exam highwall, unsafe conditions existed, inadequate ground control plan.	Driller	
5	Non-metal Mine, AL	Feb-99	Limestone	Highwall	Fall of Highwall	232	Limestone, shale & mud		Drilling hole, rock fell, hit in head, hard hat broken.	2 lb, 13 oz	Cloudy, rains	Failed to scale loose ground, method did not provide wall stability, no benching used.	Driller	
6	Coal Mine, WV	Jan-99	Coal	Spoilbank	Powered Haulage				when dumping spoil, pile failed under wheels, truck fell below.		Freeze, thaw, rain	Middle dump collapsed under truck weight.	Truck Driver	Truck
7	Coal Mine, KY	Jan-99	coal	Highwall	Fall of Highwall	60	Sandstone & shale	Faults/open joints	Drilling near highwall base, when rocks fell.	Large sections	Freeze, thaw	Unsafe ground conditions ,not corrected or posted, no new employee training given.	Driller	Drill
8	Coal Mine, KY	Oct-98	Coal	Highwall	Fall of Rock	73	Sandstone & shale		While drilling hole, large rock fell.	210 cu ft	Sunny, 84°	Loose rock not scaled, inadequate on-shift exam, ground control plan not followed.	Driller	Drill
9	Non-metal Mine, MO	Feb-97	Limestone	Highwall	Fall of Highwall				While operating, rock fell on excavator	14,400 cu ft		Hazardous ground conditions not corrected, incomplete highwall exam.	Excavator Operator	Excavator
10	Coal Mine, KY	Dec-96	coal	Highwall	Fall of Material	65	Silt, clay, sand & gravel	Highwall intersected old river channel	Loading truck when mud & water flooded backhoe.	Large volume	Rain, 32°		Backhoe Operator	Backhoe
11	Non-metal Mine, NC	May-96	Sandstone	Highwall	Fall of Highwall	30	Sandstone		End loader removing waste, worker hit by loose rocks.	3 cu ft		Highwall not scaled properly, not wearing hard hat.	Vice President	
12	Non-metal Mine, PA	Dec-96	Limestone	Highwall	Fall of Ground	44	Limestone		Standing on overhanging ledge that gave in, fell covered with rock.			Ground conditions not corrected, post blast exam of loose ground not made.	Blaster	

Source: Mine Safety and Health Administration