DEPARTMENT OF ENVIRONMENTAL PROTECTION
BUREAU OF MINING PROGRAMS

DOCUMEMT NUMBER: 563-2111-112

TITLE: Highwall Stability In Long-Term, Multiple Bench Quarries

EFFECTIVE DATE: July 22, 1998

AUTHORITY: 25 Pa. Code §§ 77.571, 77.573 and 77.594(2)(iii)

POLICY: It is the policy of the Department to ensure the stability of highwalls in long-term, multiple bench quarries in order to protect the health and safety of the public and quarry personnel.

PURPOSE: To specify the information requirements for a stability analysis and to provide procedures and evaluation criteria for reviewing requests to develop a working face for a bench greater than 50 feet (15.24 meters) or for the removal of benches below the reclamation slope or safety bench in pit-type quarries.

APPLICABILITY: This guidance is applicable to noncoal (industrial minerals) surface mine operations in consolidated rock.

DISCLAIMER: The policies and procedures outlined in this guidance document are intended to supplement existing requirements. Nothing in the policies or procedures shall affect regulatory requirements.

The policies and procedures herein are not an adjudication or a regulation. There is no intent on the part of the Department to give these rules that weight or deference. This document establishes the framework, within which the Department will exercise its administrative discretion in the future. The Department reserves the discretion to deviate from this policy statement if circumstances warrant.

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LOCATION: Vol. 12, Tab 111A
I. BACKGROUND

Section 77.571 establishes a maximum height of 50 feet (15.24 meters) for any working face in consolidated rock. This requirement may be waived. Requests for such a waiver must include a stability analysis.

II. PROCEDURE

Contents of a Waiver Request

The District Mining Office (DMO) reviews all requests for waivers to develop a working face which is greater than 50 feet (15.24 meters) or a top bench greater than 65 feet (19.81 meters). Reviews are also performed for requests to remove the lower benches on the final working face. These are benches that are below the final reclamation slope.

Either type of waiver requires that a stability analysis be submitted. The request for a waiver must also identify any man-made features within a distance equivalent to three times the maximum proposed depth of the pit measured at the final working face. The stability analysis should be prepared and sealed by a registered professional geologist or a registered professional engineer.

A request for a waiver must include a stereonet or equivalent analysis of the geologic structure at the working face and a map showing the location of any measurements (strike and dip) taken at the site, man-made features and the area for which the waiver is requested. A separate stereonet analysis should be submitted for each highwall or section of highwall where geologic structure varies. Computer programs or other applicable analyses (e.g., block wedge analysis) that would provide an equivalent analysis to the stereonet analysis are acceptable alternatives to the stereonet analysis.

Evaluating the Waiver Request

Safety is a primary concern when considering a request for a waiver to remove benches. Of initial concern is the safety of the workers within the pit or quarry. The purpose of the benches is to catch and contain rocks which might spall off of the highwall. In virtually every quarry, a certain amount of rockfall is to be expected. This condition is often minimized by scaling of the working faces. However, if significant rockfall continues after scaling, then a request to remove benches should be denied.

Any request to remove benches on final highwalls prior to reaching the maximum permitted pit depth should be discouraged unless there is a compelling reason for such removal on a site-specific basis. Removal of benches on interim or advancing highwalls will be evaluated on a case-by-case basis and may not require the same degree of analysis as bench removal on final highwalls. The Department may require wider benches on highwalls where geologic conditions create safety or stability concerns.

A stereonet analysis is used to help evaluate the potential for rockfall to occur and takes into account the planar geologic features such as joints, bedding planes and faults in relationship to the orientation of the highwall. The analysis should be reviewed based on the criteria in Appendix A and B. In most quarries, geologic conditions vary across the quarry, and often across an individual highwall. Therefore, a separate stereonet analysis should be submitted for each section of highwall where geologic conditions vary. The stereonet analysis, however, does not take into account all factors which affect stability (e.g., solution cavities, joint spacing, tension fractures). A field review of the site is essential, and considerable weight should be given to a visual inspection at the face. Photographs of the highwalls may be useful for the record. The field review should include observations of other vertical faces in the same geologic strata in the area, such as road cuts.
On a larger scale, the safety and stability of property and cultural features, such as buildings and roads which lie beyond highwalls are of equal concern. In some cases, removal of benches can result in unstable conditions which allow massive failures of large portions of the highwall. This is most likely to occur in areas of major faulting or along the contacts of geologic formations. The stability analysis should address the geologic conditions to be encountered within a horizontal distance equal to 3 times the depth of the pit. If faulting, geologic contacts, or other geologic features which could promote large scale failure are present within this area, the operator must identify the nature and character of these features and factor them into the stability analysis.

**Sample Stereonet Analysis**

The following sample stereonet analysis has been provided for the purpose of assessing the stability of the highwalls at a limestone quarry.

The quarry shape is rectangular with two of the highwalls (northeast and southwest) having a strike direction of 124°. The strike direction of the other two highwalls (northwest and southeast) is 34°. The orientation of the highwalls was measured in the field and plotted on the stereonet.

The criteria for both planar sliding and wedge failure require that dip of the plane or the dip of the intersection of two planes is greater than the friction angle and that the plane or the intersection of two planes is daylit into free space. The friction angle for limestone is known to be 30°. If there is development of clay seams along the plane the friction angle can be lower than 30°.

The following structural discontinuities have been measured in the field and plotted on the stereonet shown on Figure 1 following the procedures described in Appendix B.

<table>
<thead>
<tr>
<th>Dip</th>
<th>Dip Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bedding Plane</td>
<td>20° 55°</td>
</tr>
<tr>
<td>Joint System #1</td>
<td>68° 320°</td>
</tr>
<tr>
<td>Joint System #2</td>
<td>58° 320°</td>
</tr>
</tbody>
</table>
Sample Stereonet Analysis

Here are the results of the stereonet analysis.

The intersection of the planes of the two joint systems, measured on the stereonet, dips at 45° with a dip direction of 26°.

The intersection of the bedding plane and the plane of joint system #1, measured on the stereonet, dips at 20° with a dip direction of 41°.

The intersection of the bedding plane and the plane of joint system #2, measured on the stereonet, dips at 10° with a dip direction of 355°.
From the results of this stereonet analysis, we can draw the following conclusions:

**Southwest Highwall** - This highwall daylights the line of intersection of the planes of joint systems #1 and #2. Because the 45° dip of this intersection is greater than the 30° friction angle and the intersection dips out of the highwall into free space (daylighted) wedge failures are very likely to occur along this highwall. Removal of benches or allowing working faces greater than 50 feet (15.24 meters) should not be approved.

**Northeast Highwall** - This highwall does not daylight the intersection of the planes of the two joint systems or the intersection of the bedding plane and the joint systems. All of these intersections dip into the highwall resulting in a stable highwall. In this case the removal of benches or allowing a greater working face height would be feasible.

**Northwest and Southeast Highwalls** - On these two highwalls the intersections of the two joint systems and the bedding plane have no adverse effect on highwall stability since the dips of these plane intersections are not daylighted.

Appendix C lists several technical references on the subject of stability analysis.

**APPENDICES:**

APPENDIX A: TYPES OF ROCK SLOPE FAILURE

APPENDIX B: CONSTRUCTION OF A STEREONET ANALYSIS

APPENDIX C: TECHNICAL REFERENCES
APPENDIX A

TYPES OF ROCK SLOPE FAILURE

There are three types of rock slope failure which can occur in consolidated rock. These types of failure will occur due to gravitational forces along discontinuities in the rock units. The failures occur from movement of individual blocks along the discontinuities in a combination of failures - planar sliding, wedge sliding, and toppling failure.

*Planar Sliding* Can occur when blocks slide along a single discontinuity (e.g. bedding plane) where the dip of the plane is greater than the friction angle of the rock unit and the plane daylight into free space. In mining, daylighting is caused by the development of a highwall or working face which intersects the plane or discontinuity. Planar sliding will normally occur only if the working face is established nearly parallel to the strike of the bedding plane. See Figure 1.

*Wedge Sliding* Can occur when blocks slide along the line of intersection of two planes of discontinuity, such as the intersection of the planes of two joint systems. The dip of the intersection of the two planes must be greater than the friction angle of the rock unit and the intersection must daylight for wedge failure to occur. Wedge failure is the most common type of rock slope failure. Planar sliding is a special case of wedge sliding. See Figure 2.

*Toppling Failure* occurs in rock masses which dip steeply away from a daylighted area. If the rock mass is daylighted at a steep angle so that the center of gravity of the individual blocks in the rock mass falls within the daylighted area, toppling failure can occur. See Figure 3.
APPENDIX B

CONSTRUCTION OF A STEREONET ANALYSIS
APPENDIX C

TECHNICAL REFERENCES


