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Excavation Collapse



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1. SUMMARY

On August 22, 2006, around 11:00 a.m., a more than 40 foot high, steep excavated slope suddenly collapsed. The collapsed earth deposits buried a nearby excavator and killed the operator inside the cab. The excavator was cleaning the base of the slope when the incident occurred.

Personnel from the Puerto Rico Area Office (PRAO) of the Occupational Safety and Health Administration (OSHA) arrived at the scene within hours of the incident. The OSHA investigation began soon after the incident and included interviewing witnesses, taking photographs and collecting soil samples for classification tests. In the course of the investigation, the same personnel from PRAO made additional site visits to interview the owner and contractors, take additional photographs and collect additional contractual and technical information.

On August 24, 2006, OSHA Regional Administrator, Region II, requested the Directorate of Construction, OSHA National office, Washington, DC, to provide engineering assistance in assessing the collapse and in determining the cause of the incident. Note that we did not have an opportunity to visit the incident site and take any measurements. We reviewed the geology and the soil survey around the construction site. We examined earth deposits from the failed surface and the overall shape of the failure based on the photographs. In addition, we calculated the slope and height of the excavation from the topographic survey after the incident. Based on the above, we concluded that:

1. Most of the earth deposits in the excavation were residual soil, decomposed rock or heavily fractured rock. They were more soil-like than rock-like deposits. These deposits could at best be classified as OSHA Type B soil. They were not stable rocks.
2. For OSHA Type B soil, the excavated face must either be sloped or benched to a 1(horizontal) to 1(vertical) slope to a maximum depth of 20 feet. For an excavation greater than 20 feet deep, it must be designed by a registered professional engineer (29 CFR Part 1926, Subpart P, Appendix B, Table B-1, Note 3).
3. At the collapsed area, the slope of the excavation averaged .(H) to 1(V) and the height of the excavation was over 40 feet. In addition, a registered professional engineer did not design the excavation. Thus, the excavation subcontractor did not comply with OSHA standard 1926.652(a)(1).
4. The collapse was most probably caused by the fact that given the nature of the earth deposits, the excavated slope was too steep, i.e., .(H) to 1(V).

2. INFORMATION REVIEWED

The following is a chronological list of information received from the Puerto Rico Area Office (PRAO) during the investigation.

On August 25, 2006, DOC received 11 photographs of the collapse. These photographs were taken by the general contractor, GEC, LLC, on the day of the incident.

On August 30, 2006, DOC received 20 more photographs of the collapse. These photographs were taken by the OSHA compliance office on August 22-23, 2006. DOC also received the grading and drainage plan of the construction site (Drawing Nos. C-106 and C-107), the police report and a newspaper article describing the incident. After reviewing the above information, DOC submitted a request for additional information to the area office.

On October 16, 2006, DOC met with the area director of the OSHA area office in Hunt Valley, MD, to discuss the incident, and received the following requested information:

- Project organization chart.
- Contract Agreement between the owner, East End Plaza, LLC, and the general contractor, GEC, LLC, including the project manual, but not the contract drawings.
- Purchase Order, Subcontract Agreement between the general contractor, GEC, LLC, and the excavation subcontractor, Apex Construction Company, Inc. This document also included 14 sections of contract specifications and 6 sheets of contract drawings related to the excavation activities.
- Location and description of seven test pits performed by R & R Caribbean for the project architect, Springline Architects, LLC.
- August 22, 2006, fatal incident description by Apex Construction Company, Inc. And GEC, LLC.
- Configuration survey of the incident site after the collapse, performed by Brian Moseley & Associates, Inc. for GEC, LLC.
- 28 photographs with the position and direction of where the photographs were taken identified on the contract plan. These photographs were taken by the area director on September 1, 2006.
- A CD-R disc containing 7 photographs at the entrance of the construction site (taken on 8/24/06); 40 photographs of the damaged excavator and a general view of the site (9/26/06); 9 photographs around the boundary of the site (9/28/06); 21 photographs of the nearby sites showing the permanent slopes at the food center, home depot, and airport of St. Thomas (9/28-29/06); geology of the Puerto Rico and U.S. Virgin Islands (2002); and soil survey of the U.S. Virgin Islands (1998).

On January 19, 2007, DOC received the demolition specifications and the operation & maintenance manual of the damaged excavator, Komatsu PC220LC.

3. DESCRIPTION OF THE PROJECT AND THE INCIDENT

The Project

The project under construction was a 40,000 square foot retail and office complex with two levels of parking. It is named East End Plaza, located at the east end of St. Thomas, U.S. Virgin Islands (USVI). The two parking levels and the plaza of the project were being constructed in steps along the slope of a mountain near its toe as shown in Figures 1 and 2.

The East End Plaza, LLC, owns the project. Springline Architects, Harris Civil Engineers and Garland Wilson were the architect, civil engineer and structural engineer of the project, respectively. GEC, LLC and Apex Construction Company, Inc. were the general contractor and excavation subcontractor of the project, respectively. Except for Harris Civil Engineers from Winter Park, FL and GEC, LLC from St. Croix, USVI, all the others are local firms in St. Thomas, USVI.

The project was in the first phase of construction, i.e., excavation and site stabilization, when the incident occurred. At that time, the excavation of the parking areas into the mountain slope was almost completed. The retaining wall between the upper and lower levels of the parking area, near the middle of the project site, had been constructed as shown in Figure 4.

The Incident

On the morning of August 22, 2006, the employee/operator of the excavator (Komatsu PC220LC) used a hydraulic breaker to loosen the earth deposits from the mountainside. He also used the same breaker to loosen the base of the excavated slope to prepare the upper level of the parking area.

Around 11:00 a.m., the over 40 foot high, steep excavated slope suddenly collapsed. The collapsed earth crushed the cab side of the excavator and then buried it entirely (Figures 5 and 6). As a result of the collapse, the employee inside the cab was killed. At the time of the incident, the excavator was breaking the base of the excavated slope.

4. ANALYSIS AND DISCUSSION

Geotechnical Information

From the vicinity map of the contract drawing, G-1.01, the project site is identified at the east end of St. Thomas Island near Redhook Bay. The geological map of this location identifies the bedrock as Water Island Formation (Kw). The rocks near the ground surface are subject to weathering, such as hydrothermal alternation, silicification, oxidation and sulfidization. As a result, the rock mass has produced numerous fractures with brightly colored rocks visible at Red Hook of St. Thomas. In addition, due to heavy weathering, the strength of the rock blocks has also weakened to soil-like deposits.

Based on the soil maps, the project site is within the SrF soil unit. SrF stands for Southgate-Rock, located on the side slope of a volcanic mountain. The outcrop complex has a 40 to 60 percent slope and a 40 percent rock outcrop area. However, based on Figure 3, the slope of the original ground surface at the project site is estimated to be 40 to 45 percent and the rock outcrop is estimated to be less than 1 percent. Thus, the depth of weathering at the project site is much deeper than the soil map indicates.

Soil borings were not performed for the north excavation. The only site specific geotechnical information was based on seven test pits performed by R & R Caribbean (RRC) for Springline Architects (SLA) during the design stage. The test pits were located in the vicinity of the proposed retaining wall and building (Figure 3). The test pits were dug with a backhoe to approximately 12 to 15 feet in depth. There were no logs or reports for the test pits. However, the RRC indicated to SLA that:

“The soils located at the test pits were relatively easy to excavate and that no major rocks were encountered. The soil strata matched that of neighboring excavation cuts where no major rocks were encountered.”

The above statement is consistent with the less than 1% of rock outcrop at the project site. In addition, since the site is near the toe of the volcanic mountain, the depth of weathering should be relatively uniform around 15 feet deep.

Slope and Height of the Excavation at the Collapsed Area

Based on the original topography of the site before the excavation (Figure 3) and the corresponding configuration after the collapse (Figure 4), six cross sections around the collapsed area were developed. The location of the sections is shown in Figure 4. The first two sections (Figures 7 and 8) were to the north of the collapsed area. From these two figures, the following information was identified:

- The original ground slope varied from 41 to 45%.
- The cut slope averaged 76 degrees, approximately . (horizontal) to 1(vertical).
- The excavated elevation of the parking level 2 was about the same as the pavement elevation as indicated in Figures 1 and 2.

- The horizontal distance from the face of the retaining wall to the toe of the cut slope was 60 feet.

Figures 9 through 12 were developed using the above information. The upper portion of the cut slope in Figure 9 appeared to be intact. The earth deposits on the base of the slope appeared to be pushed over from the south during the rescue operation. This section could represent the north end of the collapse. Figures 10 and 11 were sections in the middle of the collapse. As indicated, the average thickness of the collapsed earth deposits was 8 feet.

The upper portion of the cut slope in Figure 12 appeared to be intact. The earth deposits at the base of the slope appeared to be pushed over from the north. This section could represent the south end of the collapse. Based on Figures 9 through 12, the average height of the excavation was 43 feet and the width of the collapse was 60 feet. As a result, the volume of collapsed materials is estimated as:

$$60 \text{ ft wide} \times 8 \text{ ft thick} \times 43 \text{ ft high} = 20,640 \text{ ft}^3 = 764 \text{ yd}^3.$$

Note that the above earth mass was excavated at a . (H) to 1(V) steep slope and collapsed. Thus, the earth mass could not be regarded as stable rock by OSHA definition (29 CFR Part 1926, Subpart P, Section 650(b), Paragraph Stable Rock).

Type of Earth Deposits at the Collapsed Area

Photographs of the excavated and collapsed surfaces were examined from north to south. Figure 13 represents the excavated surface north of the collapse. As discussed, the exposed surface appeared to be heavily fractured rocks with indentations and over breaks caused by the hydraulic breaker during the excavation. Figures 14 and 15 represent the lower portion of the collapsed surface at its north end. They indicate similar heavily fractured rocks with two large cavities caused either by the excavation over breaks or the collapse.

Figures 16 through 18 represent the upper portion of the collapse from north to south. The earth deposits in the upper tension zone varied from residual soil to weathered rock. Weathered rock might appear to be rock but it does not have the strength of rock, as is evident from the weathered rock being crushed to small pieces at the collapsed area.

It is interesting to examine Figures 17 and 19. In Figure 17, taken on September 1, 2006, a large weathered rock block could be seen in a seemingly stable position in the upper middle portion of the figure. But Figure 19, taken 25 days later on September 26, 2006, shows that the weathered rock block had fallen, indicating its instability.

Figures 19 and 20 show numerous brightly colored fractures indicating that the rock mass was heavily weathered. Figure 20 also represents the type of rock pieces at the center of the collapse.

Figures 21 and 22 represent the identifiable rock slabs in the excavated surface south of the collapsed area. However, this rock structure only occurred in less than 10% of the 500 foot long excavation.

The figure on the cover of this report presents the overall shape of the collapse. As shown, the collapse was in a near circular or spoon shape. Based on references presented in Figures 23 and 24, a collapse of this shape would mostly occur in overburden soil, weathered rock, waste rock or heavily fractured rock. Therefore, the earth deposits in the collapsed area could only be residual soil, weathered rock or heavily fractured rock. They were more soil-like than rock-like deposits.

Based on the three OSHA laboratory tests, samples of earth deposits collected at the incident site were classified as granular (sandy gravel) materials with no cohesion, corresponding to OSHA Type C soil. However, because of the presence of larger pieces of earth deposits at the site, the earth mass could perhaps be classified as OSHA Type B soil.

5. CONCLUSIONS

Based on the above descriptions, analysis and discussion, we reached the following conclusions:

1. Most of the earth deposits in the excavation were residual soil, decomposed rock or heavily fractured rock. They were more soil-like than rock-like deposits. These deposits could at best be classified as OSHA Type B soil. They were not stable rocks.
2. For OSHA Type B soil, the excavated face must either be sloped or benched to a 1(horizontal) to 1(vertical) slope to a maximum depth of 20 feet. For an excavation greater than 20 feet deep, it must be designed by a registered professional engineer (29 CFR Part 1926, Subpart P, Appendix B, Table B-1, Note 3).
3. At the collapsed area, the slope of the excavation averaged .(H) to 1(V) and the height of the excavation was over 40 feet. In addition, a registered professional engineer did not design the excavation. Thus, the excavation subcontractor did not comply with OSHA standard 1926.652(a)(1).
4. The collapse was most probably caused by the fact that given the nature of the earth deposits, the excavated slope was too steep, i.e., .(H) to 1(V).

6. REFERENCES

1. Geology and Hydrogeology of the Caribbean Islands Aquifer System of the Commonwealth of Puerto Rico and the U.S. Virgin Islands, by US Department of the Interior, US Geological Survey, Professional Paper 1419, 2002.
2. Geology of St. Thomas and St. John, U.S. Virgin Islands, by Thomas W. Donnelly, The Geological Society of America, Memoir 98, 1966.
3. Soil Survey of the United States Virgin Islands, by US Department of Agriculture, National Resources Conservation Service, August 1998.
4. Rock Engineering Applications, by John A. Franklin and Maurice B. Dusseault, McGraw-Hill, Inc., 1991.
5. Landslides, Investigation and Mitigation, by A. Keith Turner and Robert L. Schuster, Special Report 247, Transportation Research Board, National Research Council, 1996.

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No.	Date	Description
1	12/15/04	ISSUED FOR PERMIT REVIEW AND RECORD PREPARATION
2	1/10/05	REVISIONS TO PERMIT REVIEW COMMENTS
3	1/10/05	REVISIONS TO PERMIT REVIEW COMMENTS
4	1/10/05	REVISIONS TO PERMIT REVIEW COMMENTS
5	1/10/05	REVISIONS TO PERMIT REVIEW COMMENTS
6	1/10/05	REVISIONS TO PERMIT REVIEW COMMENTS
7	1/10/05	REVISIONS TO PERMIT REVIEW COMMENTS
8	1/10/05	REVISIONS TO PERMIT REVIEW COMMENTS
9	1/10/05	REVISIONS TO PERMIT REVIEW COMMENTS
10	1/10/05	REVISIONS TO PERMIT REVIEW COMMENTS

**SITE GRADING
 AND DRAINAGE
 PLAN**
 Scale: 1"=20'
 Date: 4/26/04
 Project No.: 04-0000
 Designer: JAL
 Checker: DMV

C-106

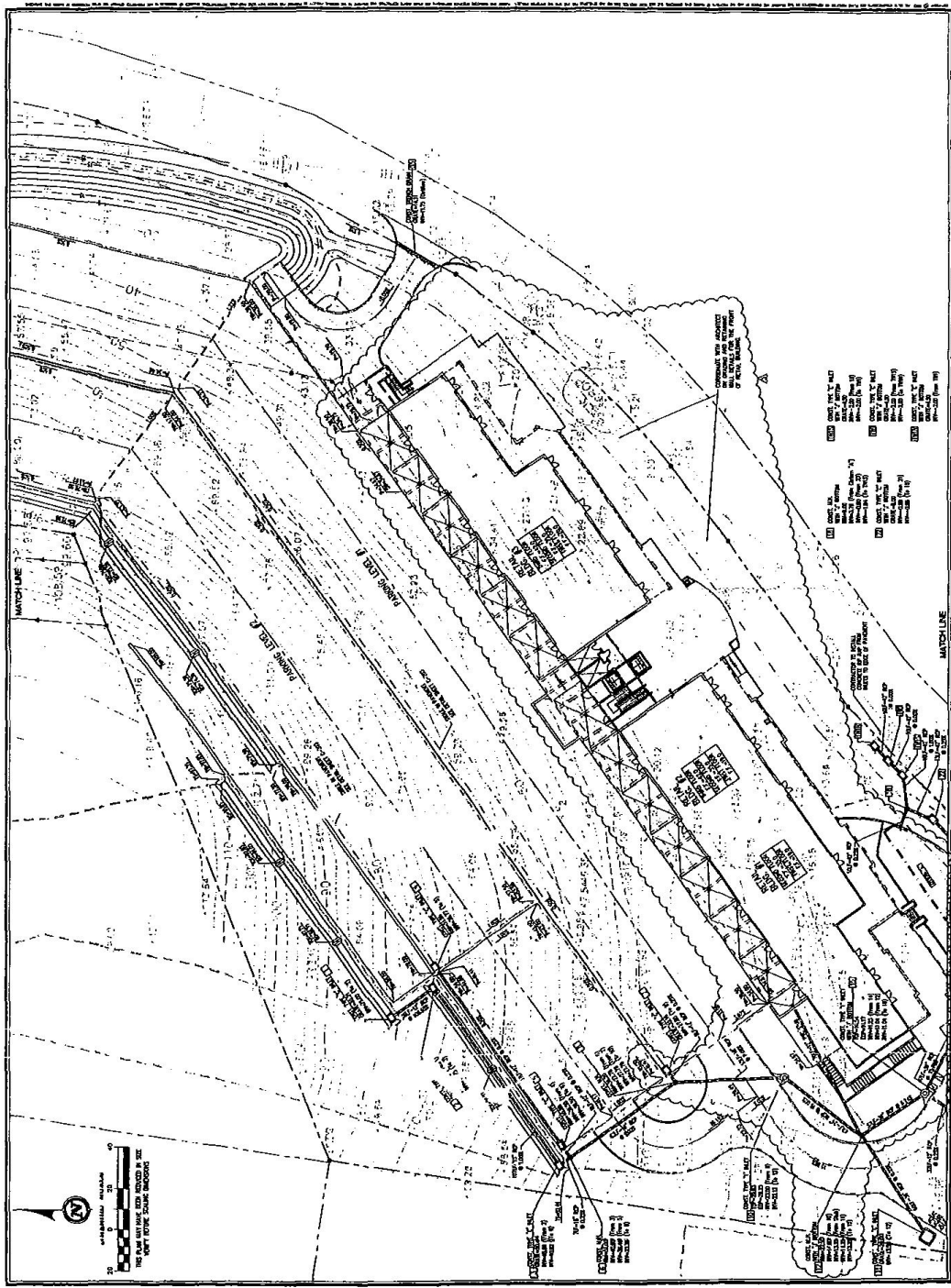


Figure 1. Project Site Grading and Drainage Plan I

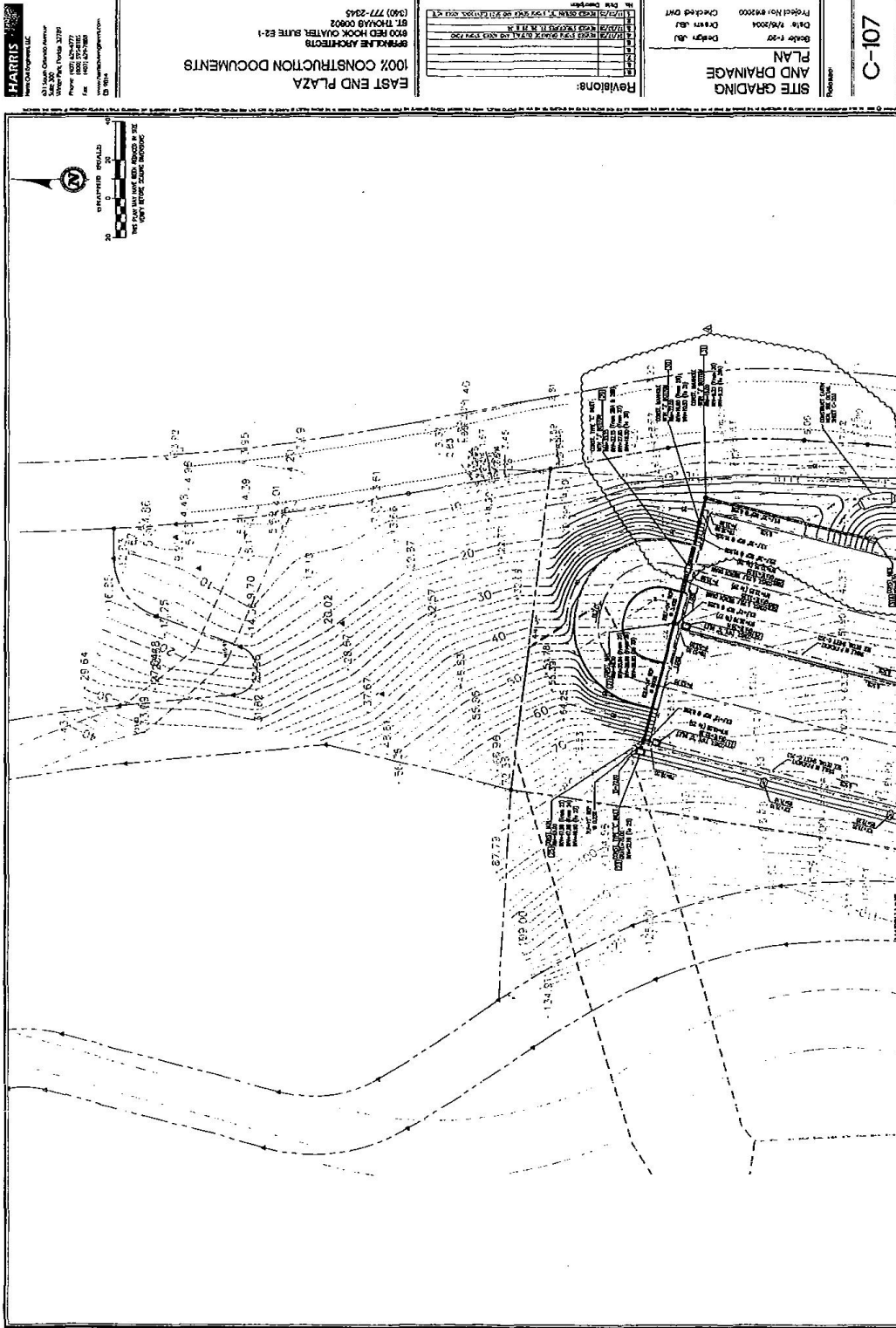


Figure 2. Project Site Grading and Drainage Plan II



Figure 5. Location of the Komatsu PC 220 Excavator during the Rescue Operation, Looking Toward North (Provided by GEC, LLC.).



Figure 6. Location of the Komatsu PC 220 Excavator during the Rescue Operation, Looking Toward South (Provided by GEC, LLC.).

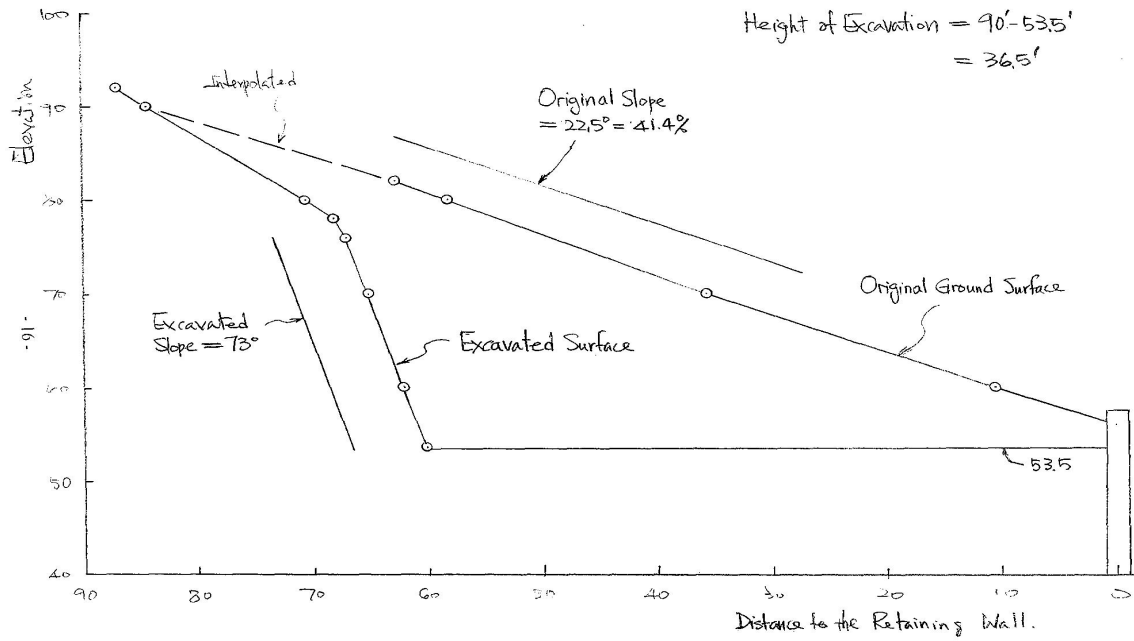


Figure 7. Cross Section of the Original Ground Surface and the Excavated Surface, North of the Collapsed Area (73 feet from the North End of the Retaining Wall).

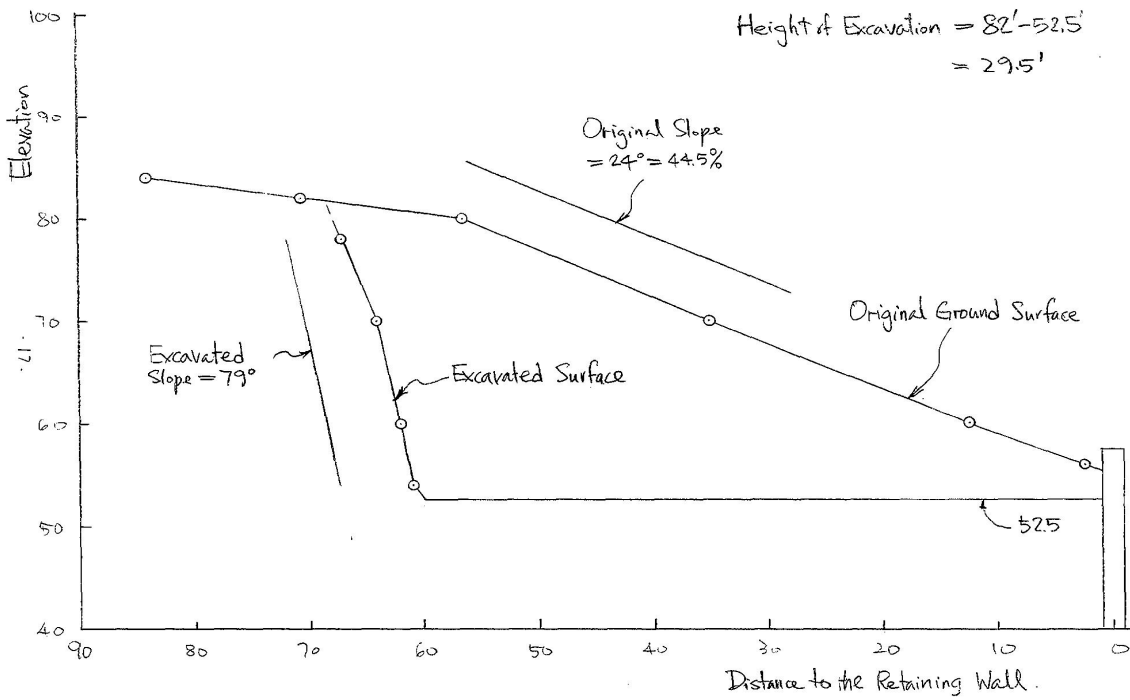


Figure 8. Cross Section of the Original Ground Surface and the Excavated Surface, North of the Collapsed Area (168 feet from the North End of the Retaining Wall).

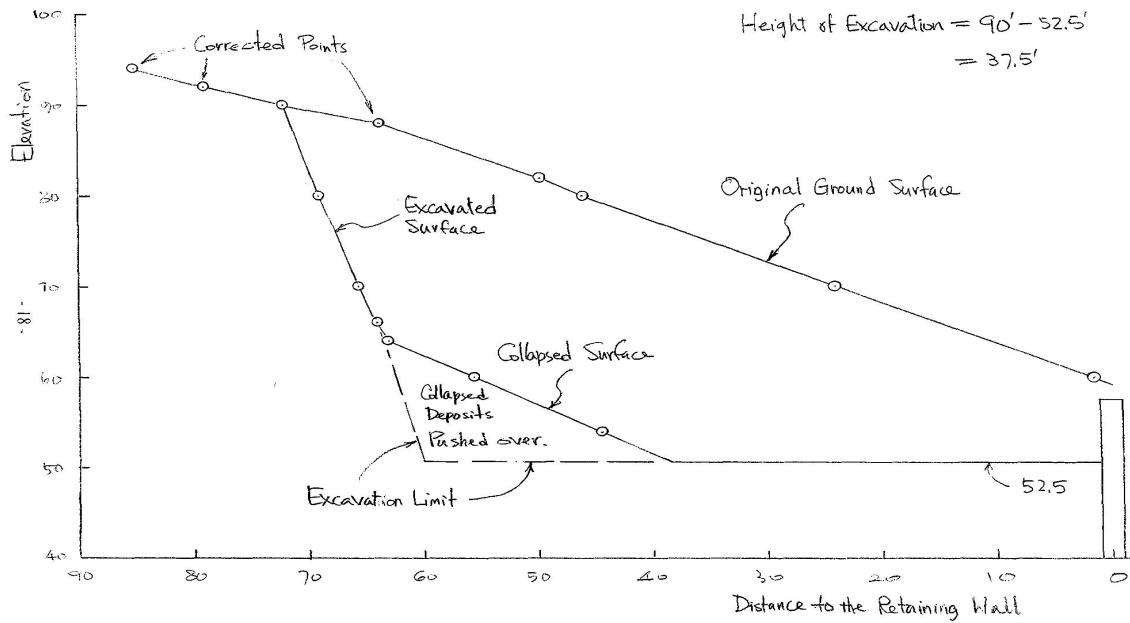


Figure 9. Cross Section of the Original Ground Surface, the Excavated Surface and the Failure Surface in the Collapse Area (50 feet from the turning Point of the Retaining Wall).

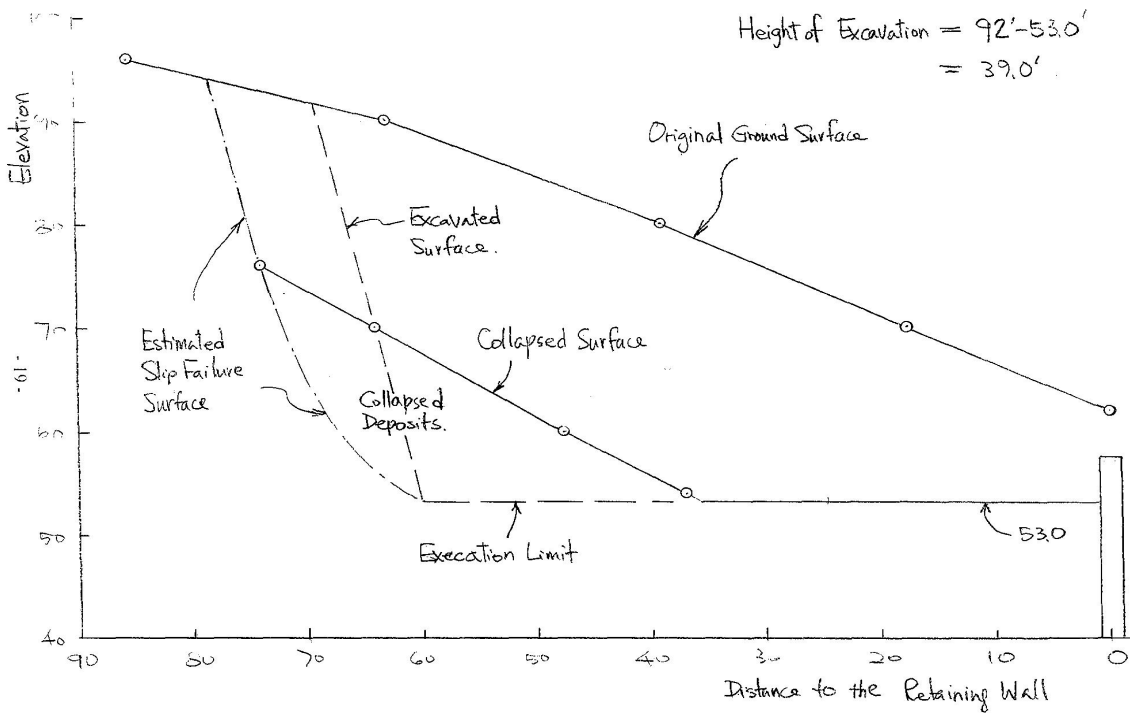


Figure 10. Cross Section of the Original Ground Surface, the Excavated Surface and the Failure Surface in the Collapse Area (70 feet from the turning Point of the Retaining Wall).

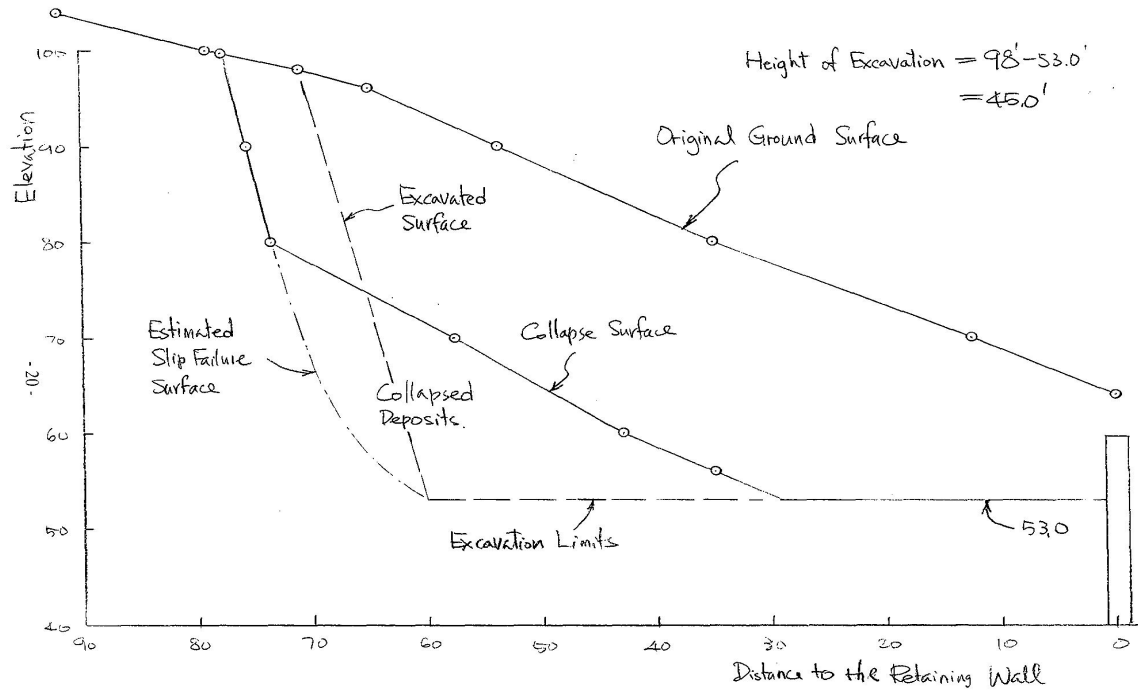


Figure 11. Cross Section of the Original Ground Surface, the Excavated Surface and the Failure Surface in the Collapse Area (90 feet from the turning Point of the Retaining Wall).

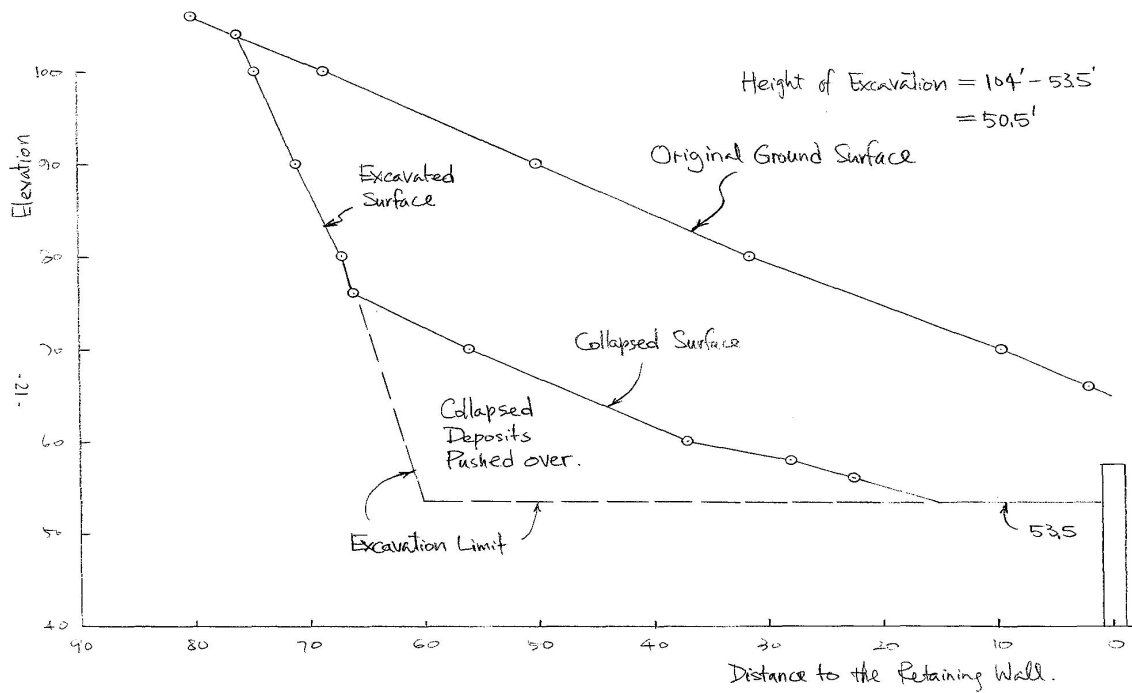


Figure 12. Cross Section of the Original Ground Surface, the Excavated Surface and the Failure Surface in the Collapse Area (110 feet from the turning Point of the Retaining Wall).



Figure 13. Excavated Surface North of the Collapsed, Looking Toward South.

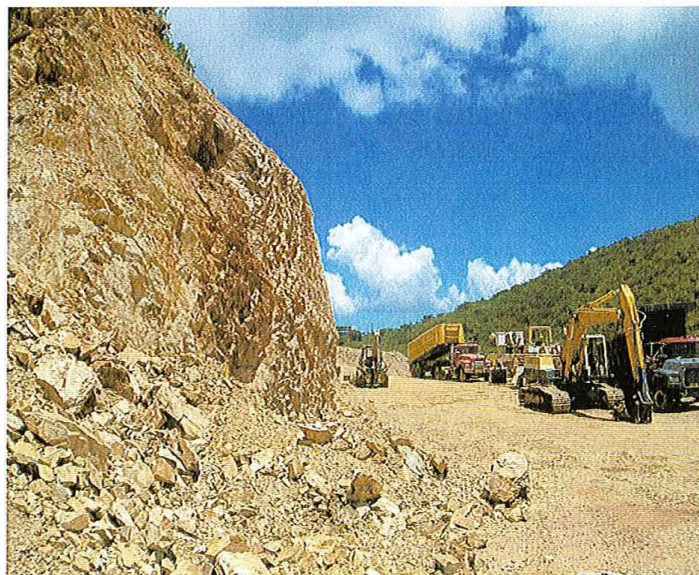


Figure 14. Lower Portion of the Collapse at its North End, Looking Toward North.

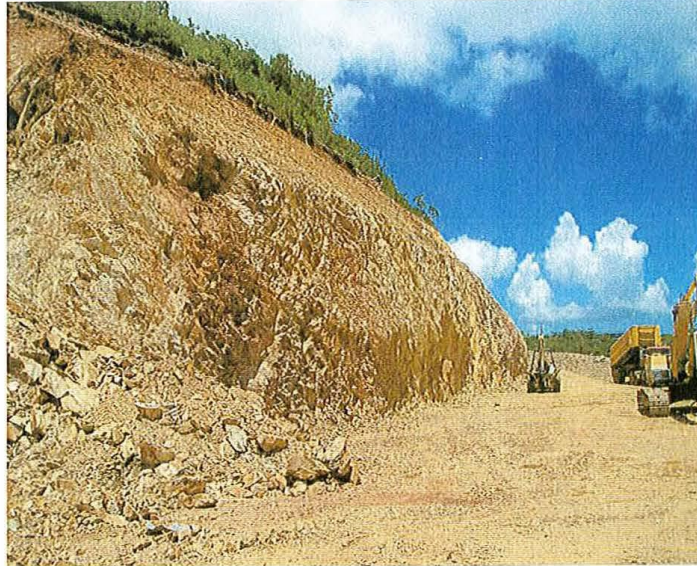


Figure 15. Another View of Figure 15, Looking Toward Northwest.

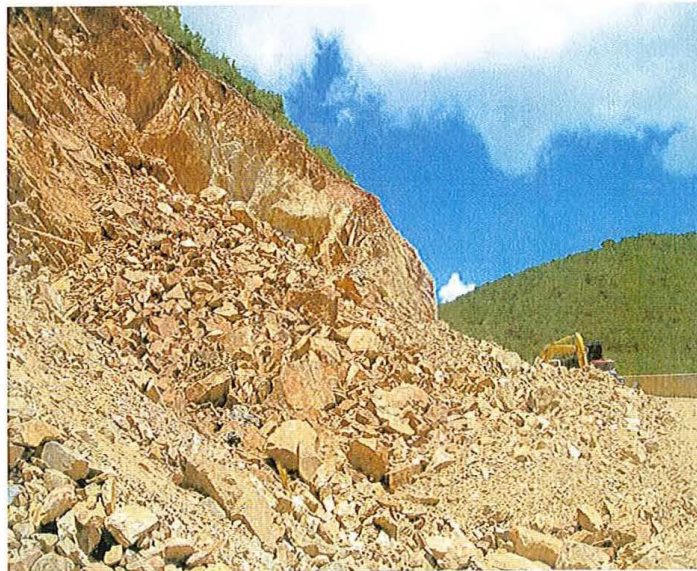


Figure 16. Upper Portion of the Collapsed Surface (North), Looking Toward North.



Figure 17. Upper Portion of the Collapsed Surface (Center), Looking Toward West.

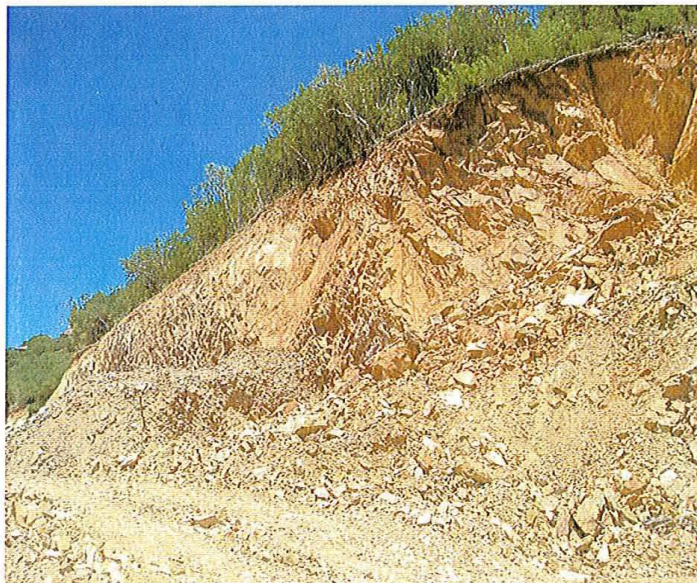


Figure 18. Upper Portion of the Collapsed Surface (South), Looking Toward South.



Figure 19. Close-up View of Figure 17 Showing a Rock Block Sled away, Looking Toward West.



Figure 20 Type and Size of Rock Pieces at the Center of the Collapse.

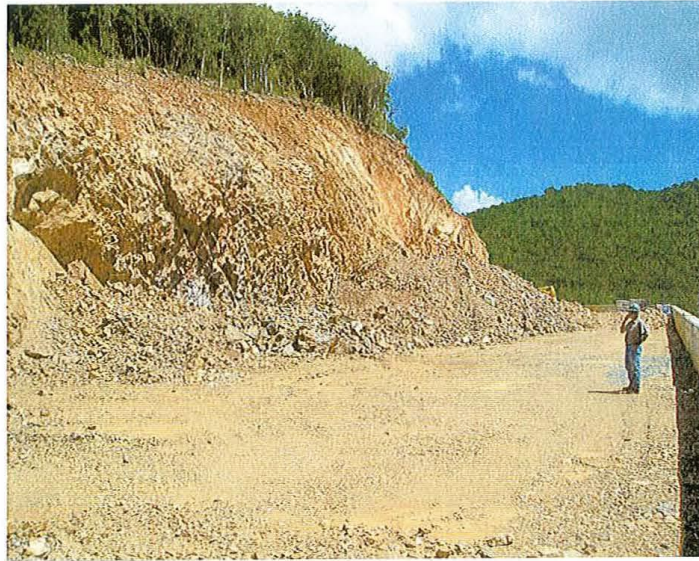


Figure 21. Identifiable Rock Slabs in the Excavation Face South of the Collapsed Area, Looking Toward Northwest.

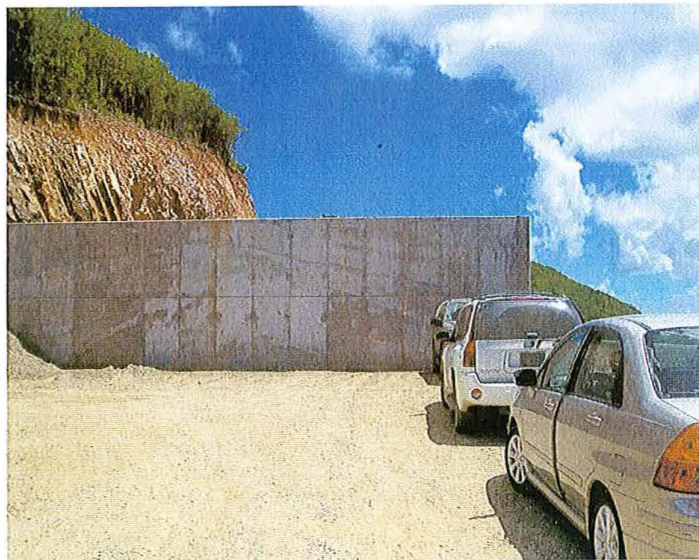


Figure 22. Another Identifiable Rock Slabs in the Excavation Face Further South of the Collapsed Area, Looking Toward North.

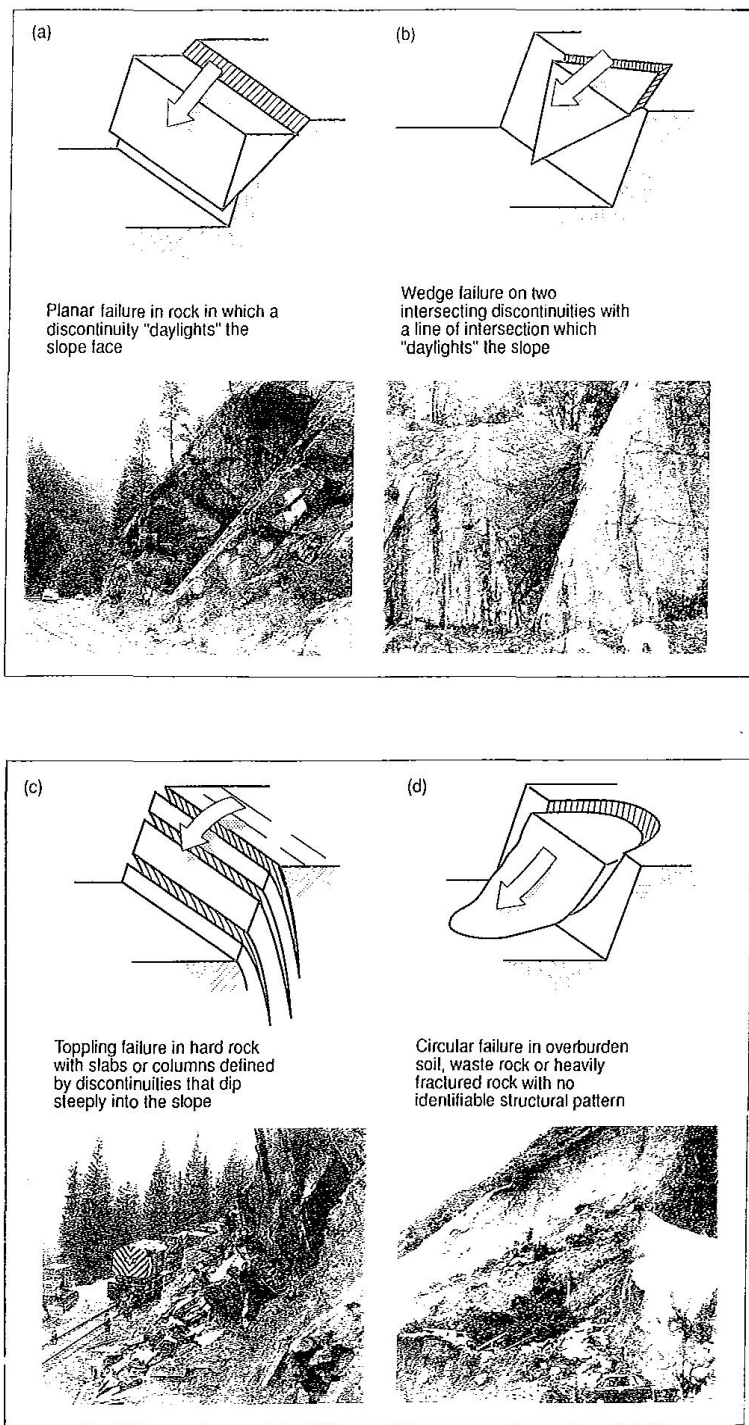
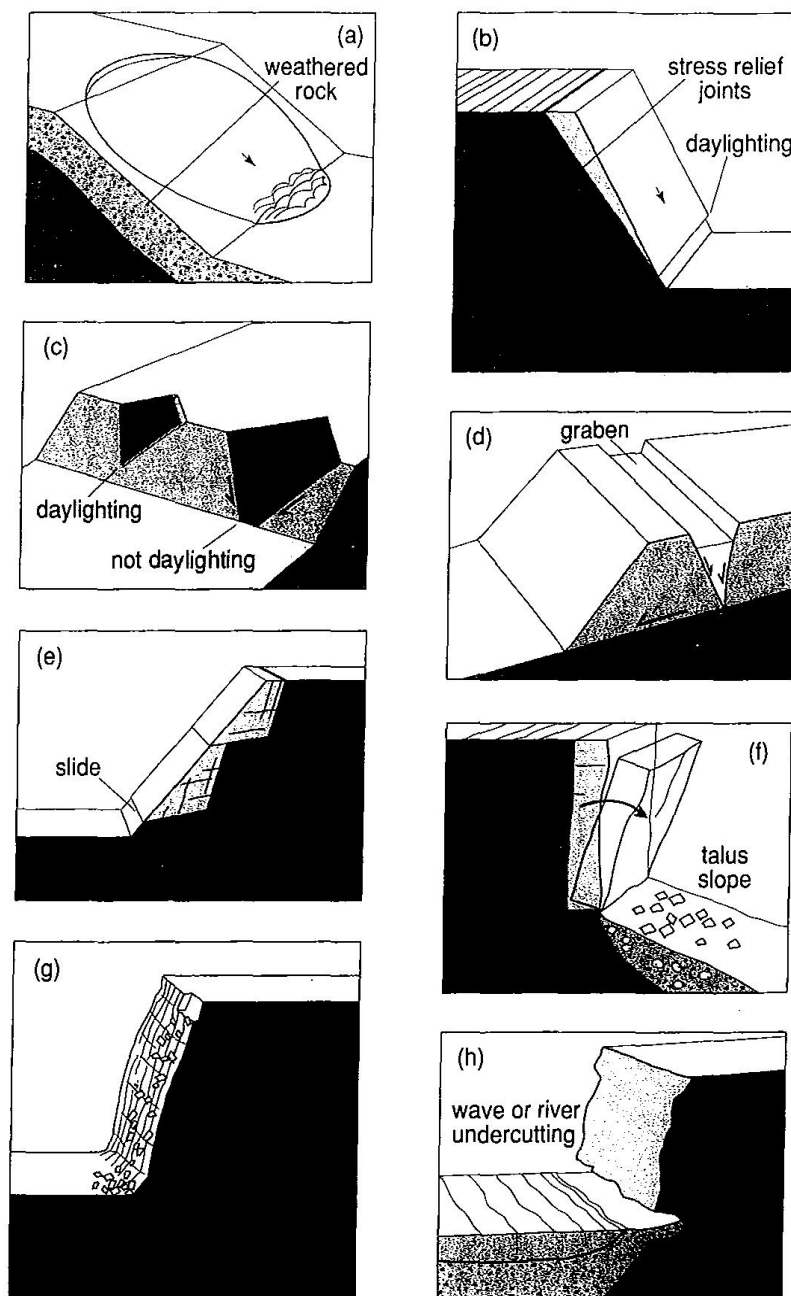


Figure 23. Types of Rock Slope Failures (Modified from Hoek and Bray, 1981 and Tuner and Schuster, 1996).



Slide mechanisms. (a) Spoon-shaped; (b) slab; (c) wedge; (d) graben; (e) stepped path; (f) toppling; (g) raveling; (h) erosion and undercutting mechanisms.

Figure 24. Type of Rock Slide Mechanisms (Modified from Franklin and Dusseault, 1991)