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ROCK NAIL DESIGN GUIDELINES FOR ROADWAY CUTS IN CENTRAL TEXAS

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16. Abstract

The objective of this project was to develop a rational design procedure for road cuts in the soft rocks of central Texas. Design recommendations were developed based on a systematic program of observation, documentation, and analysis of 53 existing rock cuts. A comprehensive field reconnaissance was conducted, and the behavior and characteristics of the rocks in natural and man-made exposures were observed and documented. The rock units in this study included primarily the Cretaceous-age sedimentary rocks that outcrop in a broad band from west of San Antonio through Austin, Waco, and Dallas. The lithologies ranged from limestones and dolostones of varying purity, through clay-rich marls and clay shales. Design guidelines are provided for rock cuts in central Texas.

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by

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conducted for the

Texas Department of Transportation

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Federal Highway Administration

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CENTER FOR TRANSPORTATION RESEARCH
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IMPLEMENTATION STATEMENT

The potential for reduced construction time and enhanced stability with "top down" construction is a distinct advantage of nailed retention systems in rock cuts. However, there is a lack of rational design procedures for these systems, and conservative design approaches that treat the rock as a soil have been used. The objective of this project is to formulate a design procedure for nailed rock excavations, which is linked integrally to the characteristics of the rock formations typically encountered in central Texas. Design recommendations are developed based on a systematic program of observation, documentation, and analysis of existing rock cuts. These recommendations include guidance on how to investigate a rock-cut site, when to use nails versus other forms of slope protection and support, and how to design nailed slopes.

Prepared in cooperation with the Texas Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration.

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The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration or the Texas Department of Transportation. This report does not constitute a standard, specification, or regulation.

There was no invention or discovery conceived or first actually reduced to practice in the course of or under this contract, including art, method, process, machine, manufacture, design, or composition of matter, or any new and useful improvement thereof, or any variety of plant, which is or may be patentable under the patent laws of the United States of America or any foreign country.

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Priscilla P. Nelson
Research Supervisor

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SUMMARY

The objective of this project was to develop a rational design procedure for road cuts in the soft rocks of central Texas. Design recommendations were developed based on a systematic program of observation, documentation and analysis of 53 existing rock cuts. A comprehensive field reconnaissance was conducted, and the behavior and characteristics of the rocks in natural and man-made exposures were observed and documented. The rock units in this study included primarily the Cretaceous-age sedimentary rocks that outcrop in a broad band from west of San Antonio through Austin, Waco and Dallas. The lithologies ranged from limestones and dolostones of varying purity, through clay-rich marls and clay shales.

Observations included exposure geometry, rock mass quality, impact of weathering, and potential failure modes. Rock cores were also obtained and laboratory tests were conducted on core samples and grab samples from exposures. In addition, the performance of existing excavations and design procedures was evaluated. Performance information that was collected and analyzed included qualitative descriptions of stability, quantitative information on maintenance frequency and effort, and quantitative information on catchment adequacy.

The performance data were analyzed to identify the most important factors affecting the performance of the studied rock cuts. The dominant mode of failure was localized raveling and differential erosion. This failure mechanism was particularly dominant in the Glen Rose Formation and the Austin Chalk. Raveling of loose blocks was also observed in the Edwards Formation where paleokarst and recent (in geologic time) solutioning has created cavities and fractures. The block sizes in both instances tended to be comparable in dimension to the bedding thickness, on the order of 0.5 m. Increased weathering and block fallout were associated with groundwater seepage from the cut or overland run-off flowing down the cut surface. Large-scale planar or wedge failures due to continuous, steeply dipping discontinuities were observed in only 3 of the 53 road cuts studied. In all cases, these failures were associated with faulted zones within the Glen Rose Formation, although similar conditions exist within the Austin Chalk and to a lesser extent within the Edwards Formation.

Conventional information from borings provided limited information in predicting the performance of studied rock cuts. The quality of the rock core (i.e., the rock quality designation, RQD) did not correlate well with stability. While high RQD values are generally associated with good performance, low RQD values are not necessarily associated with poor performance. For example, the Edwards Formation generally had the lowest core quality, yet the slopes performed the best because the rock matrix in solution collapse zones fractured readily when cored but was

cemented in situ. Stratigraphic information from borings, such as the presence of thick marly layers, was the most valuable type of information. It was found that differences in slake durability of greater than 20 to 30 percent between individual layers within a slope indicated a high potential for differential erosion. However, the absolute magnitude of slake durability, or other related properties such as unconfined compressive strength, were not effective indicators of this failure mode.

Maintenance requirements tended to be greater for cuts susceptible to raveling and differential erosion, cuts with groundwater seepage, and taller cuts. Benches were effective at reducing the slope height and, therefore, reducing the maintenance requirements. However, benches were only effective if they were wide enough to catch rock fall from the slope above and cleaned frequently. Several of the studied slopes had benches that were filled with debris and could not be accessed for cleaning. Flat catchments to collect rock fall were effective if the width was greater than one-half the slope height. Water seepage and pressures promoted rock mass deterioration. The few rock cuts containing rock nails have all performed well to date. The nails and facing materials have prevented raveling and erosion that has occurred in other cuts at the same sites.

Design guidelines are provided for rock cuts in central Texas based on this study. A site investigation program consisting of a review of published geologic maps and literature, local experience, the data included in this report, and a field reconnaissance of the site and vicinity will be adequate in most instances. Additional investigation work, such as borings and laboratory testing, are recommended only when potentially continuous discontinuities trend nearly parallel to the slope face and dip toward the slope; if the slope is to be left unsupported with a narrow catchment area (less than 0.5 times the slope height); and when the slope is to be supported with rock nails.

In most instances, near-vertical, 10 to 30-m high rock slopes or cuts in the formations common to central Texas can be left unprotected and unsupported if an adequate catchment area (of at least 0.5 times the slope height) is provided at the toe to prevent rockfall from entering the roadway.

In areas where adequate catchment cannot be provided due to right-of-way or other geometrical constraints, the slope should be protected from raveling and differential erosion with a thin layer of fiber reinforced shotcrete at the slope face. Spot nailing is recommended for supporting larger blocks (on the order of several meters in size) that may be unstable. Seepage and surface water control will also be helpful in minimizing raveling and erosion.

In areas where external loads are to be supported near the crest of the rock cut, a pattern of short rock nails is recommended in addition to the shotcrete. Additional, longer rock nails should be installed near the slope crest if the external loads are large (e.g., a bridge abutment foundation).

If continuous, steeply dipping discontinuities will daylight at the cut face, then rock nails should be installed across the discontinuity to support the potentially unstable wedge. This recommendation is intended for both slopes with and without external loads if a large-scale planar or wedge failure is possible. A design equation and design charts are presented to estimate the required nail loads. Again, fiber reinforced shotcrete should be applied at the cut face to prevent localized raveling and differential erosion. Drainage should be provided behind the shotcrete and within the slope to prevent build up of water pressures.

CHAPTER 1. INTRODUCTION

1.1 Objective

The Texas Department of Transportation (TxDOT) has designed and constructed a number of excavations and nailed walls in both soil and rock. The possibility for reduced construction time and enhanced stability with "top down" construction is a distinct advantage for nailed retention systems. However, because of a lack of design procedures and data for the relatively soft rocks in Texas, designs have been developed using a conservative approach similar to that used for soil excavation support with nails.

The response of reinforced rock slopes is distinctly different from nailed soil slopes due to differences between rocks and soils. With soils, deformation occurs as a result of strains throughout the soil mass and the mass behaves essentially as a continuum. In contrast, rock response is controlled by deformations along discontinuities such as fissures, cracks, joints and faults. Accordingly, different design approaches are required for the design of nailed slopes in rock and soil.

The objective of this project is to formulate a rational design procedure for nailed rock excavations, which is linked integrally to the characteristics of rock formations typically encountered in central Texas. The design recommendations will include guidance on how to investigate a site, when to use nails versus other forms of slope protection and support, and how to design nailed slopes.

1.2 Approach

The design recommendations have been developed based on a systematic program of observation, documentation and analysis of existing rock cuts in central Texas. The primary study districts are shown on Fig. 1.1; several rock cuts in other TxDOT districts were included as well. A comprehensive field reconnaissance has been conducted at fifty-three sites, and the behavior and characteristics of the rocks in natural and man-made exposures have been systematically observed and documented. The rock units in this study have included primarily the Cretaceons-age sedimentary rocks that outcrop in a broad band from west of San Antonio through Austin, Waco and Dallas. The lithologies range from limestones and dolostones of varying purity, through clay-rich marls and clay shales.

Observations have included exposure geometry, rock mass quality, impact of weathering, and potential failure modes. Rock cores have also been obtained and laboratory tests have been conducted on core samples and grab samples from exposures. In addition, the performance of existing excavations and design procedures has also been evaluated. Performance information that was collected and analyzed included qualitative descriptions of stability, quantitative information on maintenance frequency and effort, and quantitative information on catchment adequacy. Finally, theoretical and numerical analyses have been performed to gain insight into the behavior of nailed cuts in rock. While the design recommendations are specifically for central Texas, the methodology developed for this project can be applied to other geologic formations encountered in TxDOT construction.

1.3 Report Organization

This report is organized into nine chapters and five appendices containing supporting materials.

Chapter 2 provides a brief overview of the regional geology encountered in exposures in central Texas.

Chapter 3 contains a description of rock nailing technology.

Chapter 4 provides a detailed description of the implemented program of field reconnaissance, data collection, site investigation, and laboratory testing. Appendices A, B, C and D contain the field data forms, maintenance data, boring logs and laboratory test results, respectively.

In Chapter 5, the field performance data are summarized by district. The geologic formation, slope height and length, method of support, and observed failure modes are tabulated for each site. In addition, rating schemes are developed and implemented to quantify the stability of different cuts based on visual observations, maintenance requirements based on documented maintenance information from TxDOT, and the adequacy of catchment areas to prevent rockfall from entering the roadway.

The performance data are analyzed in Chapter 6. Comparisons are made between observed performance and that predicted by conventional rock mass classification schemes. Additional factors that affect the performance of these cuts in central Texas but are not necessarily included in conventional schemes are also identified. Catchment design procedures are also evaluated within the context of observed catchment performance. The detailed graphical and statistical analyses that support the work summarized in Chapter 6 are contained in Appendix E.

Chapter 7 addresses the design of rock nails. The tensile capacities are estimated for grouted nails in the rock formations common to central Texas. Two design approaches are proposed for different rock types and conditions. The first approach treats the nails as structural members that support the rock and stabilize the rock mass, and is appropriate for sites in faulted areas where steeply dipping, continuous discontinuities that daylight into the rock face may be present. The second approach treats the nails as low-capacity reinforcing members that bind the rock mass together and prevent localized raveling and degradation. Design charts and guidelines are provided for estimating nail loads and determining required nail spacings and lengths. Guidelines are also included for facing material at the rock surface.

Chapter 8 identifies and discusses the advantages and disadvantages of alternative control measures that can be used in combination with nails or in place of nails.

Chapter 9 provides the major conclusions from this project and a set of design guidelines for rock cut designs in central Texas.

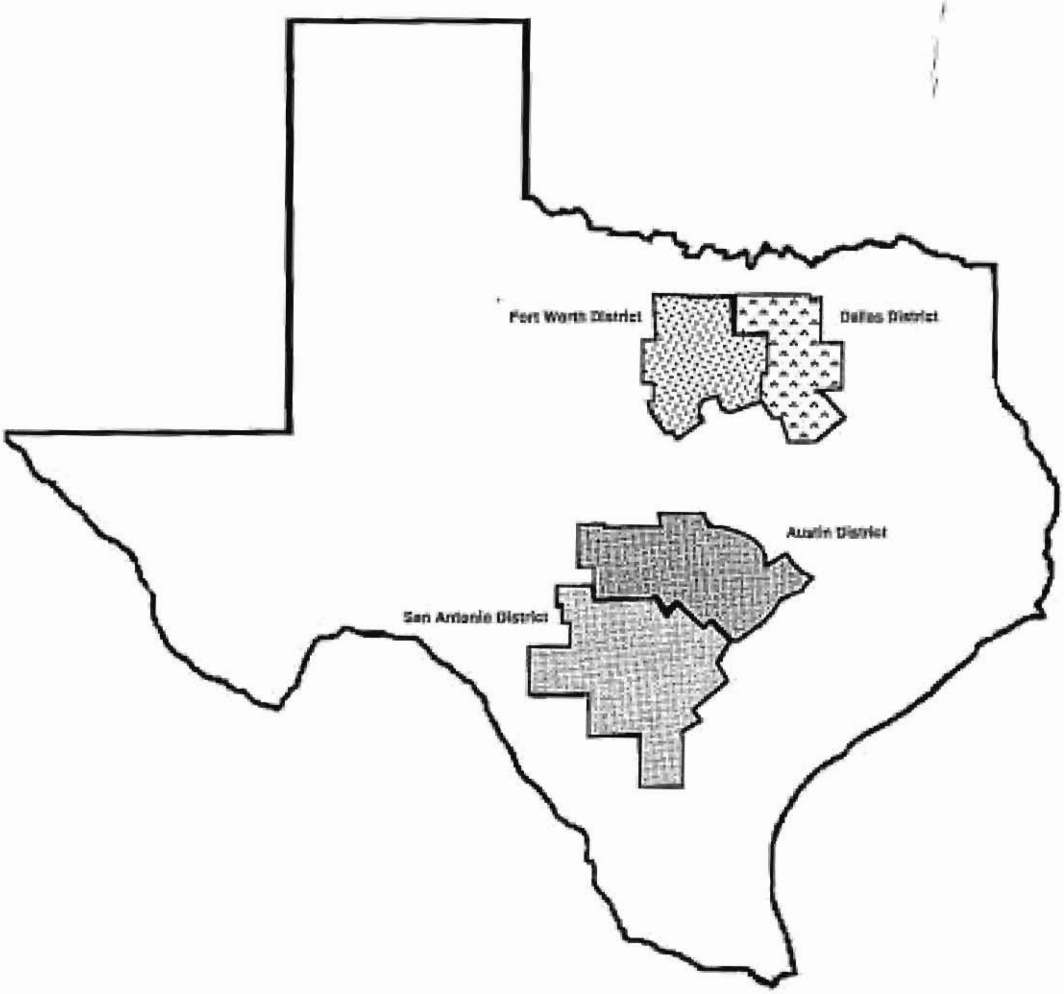


Fig. 1.1 Boundary Map of the Primary Study Districts in Texas.

CHAPTER 2. SUMMARY OF REGIONAL GEOLOGY

2.1 Introduction

The research conducted for this project was concentrated in the Dallas, Fort Worth, Austin, and San Antonio Districts of TxDOT (Fig. 1.1). The rock cuts in these districts are primarily within Cretaceous-age (66 million years ago to 144 million years) formations, including the Austin Group, the Edwards Formation and the Glen Rose Formation. Exposures of the Walnut, Comanche Peak, Winchell, and Wolf Mountain Formations were also encountered at a few locations. A summary of the regional geology in central Texas is presented in this chapter based on published literature as well as observations and experiences of the authors.

2.2 Dallas District

The Austin Group is the most predominant "soft rock" formation exposed in the Dallas area. The Austin Group, commonly referred to as the Austin Chalk, was deposited during the Cretaceous Period and outcrops in a northeast-southwest band that includes a significant portion of Dallas and surrounding areas to the north and south of the metropolitan area. The Austin Chalk has been subdivided into three separate members in the Dallas area based on lithology. The lower member is 61 m thick and consists of 0.6 to 1.5-m thick beds of chalk (soft limestone) interbedded with 0.3 to 0.6-m thick beds of marl (Allen and Flanigan, 1986). Marl is a hard calcareous clay or compact, impure limestone. The middle member is approximately 67 m thick and consists of 0.6 to 1.5-m thick beds of marl interbedded with 0.3 to 0.6-m thick chalky limestone beds. The upper member is similar in lithology to the lower member and averages 49 m in thickness. The Austin Chalk has a maximum thickness of about 206 m in Dallas County (Allen and Flanigan, 1986). The unweathered rock is light gray and weathers to a dull tan color. The Chalk also contains seams and beds of bentonitic material. Beds dip gently to the southeast at an approximate angle of 3 degrees toward the East Texas Embayment, a large broad basin marking the inland edge of the Gulf Coastal Plain.

Major fault zones in the Dallas District are associated with the Balcones Fault Zone to the west of the Dallas area. Blakemore (1939) studied the area faults and found them to be dip-slip normal faults generally striking N 10° W and with vertical displacements usually less than 4.5 m. Woodruff (1980) put the age of the faulting at early Cretaceous to Miocene. Joint systems were also studied by Blakemore (1939) and were found to be related to the faults. A major joint set strikes N 65° E and controls drainage patterns of small tributaries in the area.

The Austin Chalk is underlain by the Eagle Ford Formation and overlain by the Ozan Formation in the Dallas area. These two formations are composed of montmorillonitic clay/shale and marl, respectively. Neither of these formations was studied as part of this project. However, the Eagle Ford Formation controls the stability of cuts where its contact with the overlying Austin Chalk is exposed (i.e., White Rock Escarpment). The Eagle Ford is highly susceptible to erosion and typically erodes out from under ledges of Austin Chalk creating cantilevered beds which then break due to lack of support. A geologic profile of Dallas County is shown in Figure 2.1.

2.3 Fort Worth District

One exposure in the Fort Worth District was located at the contact between the Winchell Limestone and the Wolf Mountain Shale. These two formations are Pennsylvanian in age and are the only non-Cretaceous formations studied as part of this project. Another site was located at an outcrop of the Comanche Peak Limestone. Brief descriptions of each formation follow.

Winchell Limestone and Wolf Mountain Shale: The Winchell consists of interbedded limestone and shale. The limestone is fine-grained and thin to thick bedded. Shale is only present in the upper part of the formation, and is about 1 to 5 m thick. Total thickness of the Winchell near the site observed by Galvan (1994) is about 63 m. The Wolf Mountain Shale directly underlies the Winchell and consists of 30 to 90 m of gray shale with thin lignite and sandstone interbeds (BEG, 1972).

Comanche Peak Limestone: The Comanche Peak is a fine grained, clayey, nodular, burrowed limestone about 5 to 7 m thick (BEG, 1972). Burrows are tubular holes created by marine organisms during deposition of the material. Generally, the burrows are filled with calcareous material that is typically slightly different in color and texture than the surrounding rock.

2.4 Austin and San Antonio Districts

The Glen Rose and Edwards Formations are the predominant rock formations exposed in roadway cuts in the western portions of the Austin and San Antonio Districts. The Edwards is the younger of the two and thus overlies the Glen Rose, except in parts of the Austin District where the two are separated by the Walnut Formation. Descriptions of each of these formations are given in the following sections. A geologic profile of the Cretaceous rocks is shown in Figure 2.2.

2.4.1 Glen Rose Formation

The Glen Rose Formation is the oldest and most extensive rock formation that outcrops in the two districts. It outcrops in major portions of Travis, Hays, Burnet, Blanco, and Gillespie

Counties in the Austin District and Kerr, Kendall, Bexar, Medina, Bandera, and Comal Counties in the San Antonio District. Generally, the formation is subdivided into two distinguished members (Upper and Lower Glen Rose) separated by a Corbula (fossil) bed. However, in the Austin metropolitan area, the Glen Rose has been subdivided into five members (Rhodda, 1970). The oldest member, Member 1 consists of gray to tan, thin bedded, nodular limestone, marly limestone, and marl. A large portion of this member is also burrowed. The thickness of Member 1 is about 75 to 90 m in the Austin area to 150 m in the San Antonio District. Member 2 directly overlies the Corbula bed and consists of thin to thick bedded, gray to tan interbedded limestone and marl (Rhodda, 1970). The harder, thick limestone beds form resistive ledges which are visible along natural slopes. The thickness of Member 2 is approximately 36 m. Member 3 consists of about 21 m of thin to medium bedded interbedded gray-brown dolomite, dolomitic limestone, and gray and tan limestone, marly limestone, and marl. The dolomitic beds are more common in the lower 9 m. Member 4 is about 36 m thick and generally resembles Member 2. This member forms steep slopes and the harder limestone beds form resistive ledges. The upper-most member, Member 5, consists of about 30 to 35 m of thin bedded, gray-brown, porous dolomite and dolomitic limestone (Rhodda, 1970). Outside of the immediate Austin vicinity, Members 2 through 5 are not mapped separately but are grouped together as the Upper Glen Rose. Member 1 is thus referred to as the Lower Glen Rose. The total thickness of the Glen Rose in the region of study varies from 150 m in the northern part of the Austin District (Garner, 1976) to 270 m in the San Antonio District (BEG, 1983).

The marly beds, and to some extent the more dolomitic beds, are less resistant to erosion than the harder limestone beds, and thus help create a stair-step topography in the Glen Rose. This is a distinctive feature that can be seen on many of the hillsides in west Austin and the Texas Hill Country to the west and southwest. The Glen Rose is exposed along numerous road cuts in Austin and in the counties west and southwest of Austin. High, near vertical exposures of the Glen Rose can also be seen along the Colorado and San Gabriel Rivers in the Austin District, and the Medina, Frio, Guadalupe, and Sabinal Rivers in the San Antonio District, as well as the numerous tributaries that dissect the region.

2.4.2 Walnut Formation

The Walnut lies stratigraphically between the Glen Rose and Edwards and consists of two members each about 10 m in thickness. The lower member, known as the Bull Creek Member is a medium grained, burrowed, resistant limestone. The upper Bee Cave Member is described as an extensively burrowed, nodular, fossiliferous, limestone, marly limestone, and marl (Rhodda, 1970).

2.4.3 Edwards Formation

Like the Glen Rose, the Edwards is also a Cretaceous-age limestone and dolomite formation. Stratigraphically, the Edwards directly overlies the Glen Rose except in the Austin area where the two are separated by the Walnut Formation. The Edwards outcrops extensively in western Williamson and southwestern Travis County (west of the Balcones Fault Zone) in the Austin District. In the San Antonio District, the Edwards outcrops west of IH-35 in Comal and northwest Bexar Counties, and also outcrops extensively in Kendall, Kerr, Medina, and Bandera Counties.

The Edwards in the Austin area has been subdivided into four members by Rhodda (1970), although these members not mapped separately. Member 1, the lowest member, consists of porous dolomite, dolomitic limestone, and hard crystalline limestone. Chert is abundant in Member 1, and the top of this member is marked by a 6-m thick solution collapse zone which is a result of groundwater circulation and dissolutioning of gypsum-anhydrite within the rock unit (Rhodda, 1970). This zone is typified by caves, solution collapse breccia, red clay, and large calcite crystals. The collapse zones typically are filled with rock fragments and soil (breccia). The collapse occurred during or shortly after deposition (Rhodda, 1970), and the collapse zones are often reconsolidated or cemented The total thickness of Member 1 is about 60 m, although the entire member is not exposed in Austin. Member 2 is about 13 m thick and is composed of fine to medium grained, hard, porcelaneous limestone. The lower beds are folded and fractured due to the collapse in Member 1 (Garner, 1976). Member 3 is 3 to 4.5 m thick and consists of softer nodular, marly limestone interbedded with flaggy limestone. Finally, Member 4 resembles Member 2 in lithology and thickness, although it contains a thin solution collapse zone in the middle.

In the San Antonio area and along the Balcones Fault Zone, the Edwards is mapped as a single unit presumably because of complex structural geology as a result of faulting. The thickness of this undifferentiated Edwards is about 90 to 150 m. North and west of the fault zone, the Edwards is divided into two separate mappable units. The lower member is known as the Fort Terret Member which consists of three different lithologic zones. The basal third is described as nodular limestone with a thin, yellow, fossiliferous clay bed at the base (BEG, 1983). This clay bed serves as a marker between the Fort Terret and the underlying Glen Rose. The middle third is cherty, fossiliferous limestone and dolomite, and the upper third of the member consists of porcelaneous, aphanitic limestone, collapse breccia, chert and recrystallized limestone. Total thickness of the Fort Terret is about 70 to 90 m.

Overlying the Fort Terret is the Segovia Member which is a cherty, fossiliferous limestone at the top, followed by porous, massive to thin bedded dolomite with collapse breccia in the middle third, and marly limestone and marl at the base (BEG, 1983). The thickness of the Segovia is 90 to 115 m.

2.5 Structural Geology

The basic geologic structure of the Austin-San Antonio area is a gently dipping homocline broken up by faulting in the area known as the Balcones Fault Zone, which consists of one major normal fault and numerous other smaller normal and drag faults. The broad regional dip of bedding is to the southeast at less than 3 degrees. On the small scale of individual slopes, dips can be approximated as horizontal. In the Austin area, however, the beds of the basal Cretaceous rocks (i.e., Glen Rose, Walnut, Edwards) dip gently to the northeast into the Round Rock syncline (Tucker, 1962). Within the Balcones Fault Zone, dips are less predictable and vary considerably.

The Balcones Fault system is a belt of northeast trending dip-slip normal faults which strike at about N40°E (Rhodda, 1970). Displacements vary from less than a meter to 180 m, but most mapped fault displacements are less than 15 m. Faults with displacements less than about 3 m are generally not mappable outside of road and stream cut exposures. Dips of the faults typically range from 55 to 75 degrees. Some minor localized folding and faulting is present in and above solution collapse zones in the Edwards.

According to Rhodda (1970), two major pairs of joint sets are common in the Austin area. One joint pair strikes at N40°E and N45°W and the other at N10°W and N80°E. No information was found on jointing in the San Antonio District.

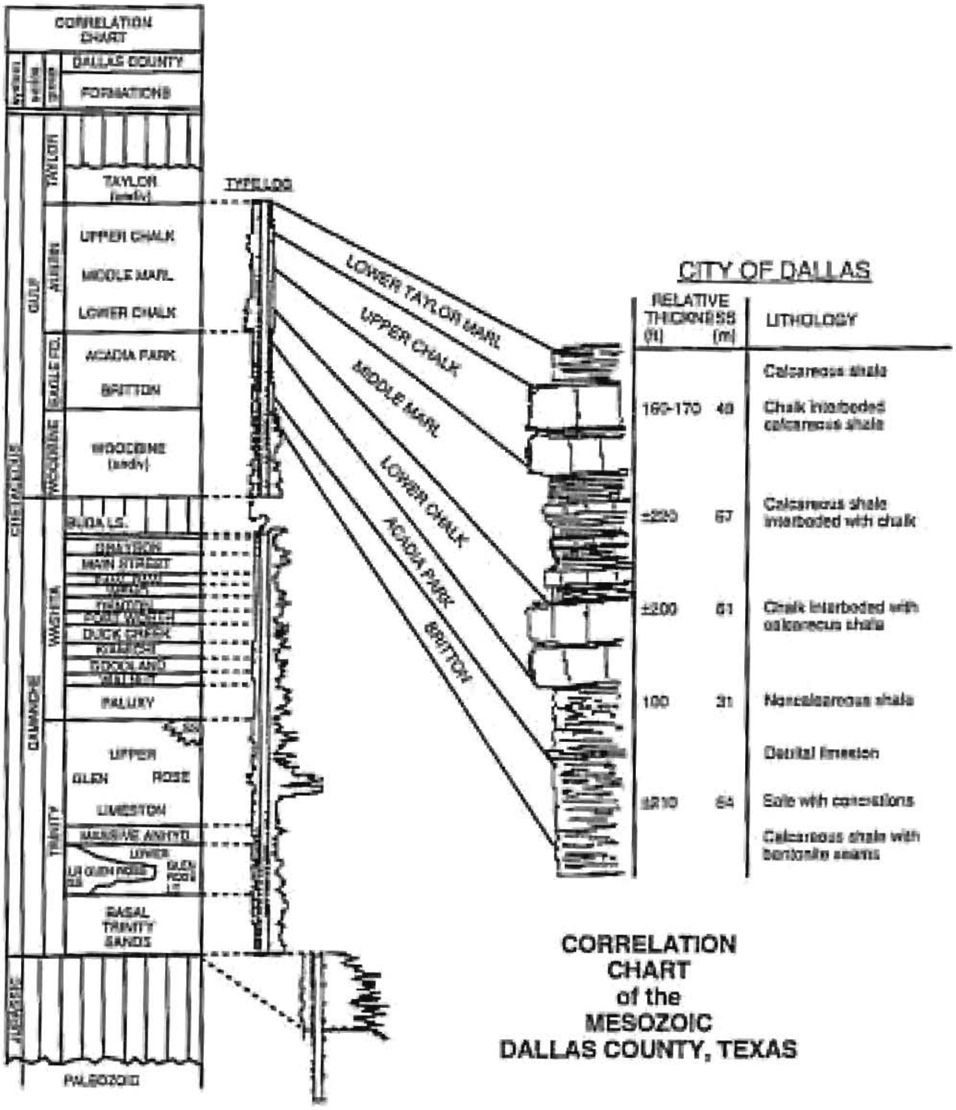


Fig. 2.1. Geologic Profile of Dallas County (Allen and Flanigan, 1986).

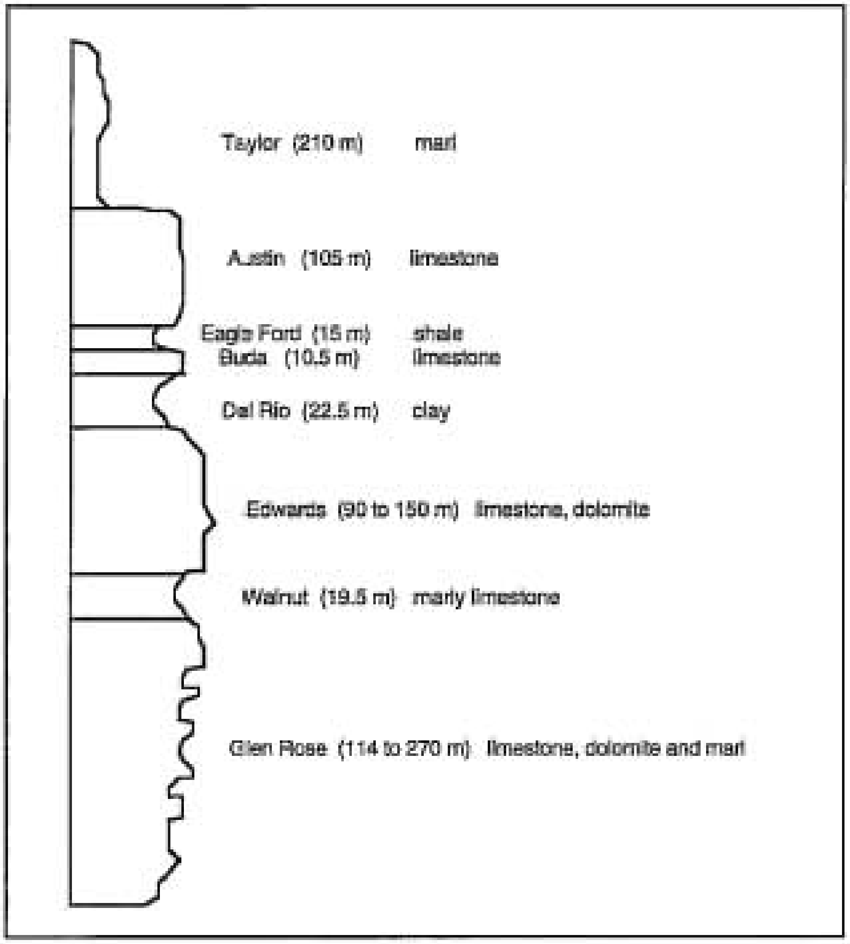


Fig. 2.2. Geologic Profile of Cretaceous Rocks in Austin and San Antonio Districts.

CHAPTER 3. ROCK NAIL WALLS

3.1 Introduction

Highways in central Texas are often constructed with vertical cuts or slopes excavated into the rock units described in Chapter 2. These cut slopes range in height from less than 3 m to greater than 30 m, and a variety of retention systems have been used to stabilize these excavations. Rock nail anchor retaining walls are one type of retention system that has been used recently. This chapter provides background on the principles behind rock nailing and the materials used in the construction of rock nail walls.

3.2 Rock Nail Retaining Structures

Nailed walls (Fig 3.1a) are constructed using a "top-down" construction procedure. In a "top-down" procedure the reinforcement is installed as the excavation progresses. This is in contrast to "bottom-up" procedures, in which the excavation is completed to full depth before a wall is built. "Bottom-up" procedures are used to construct, for example, conventional retaining walls and mechanically stabilized earth walls (Fig 3.1b). A drawback to "bottom-up" construction is that the full excavation is made before the wall is constructed. This requires the use of right-of-way behind the excavation which may not be available. It also requires the replacement of the natural material with select granular fill. In contrast, a rock-anchored wall generally refers to a conventional reinforced-concrete wall, where loads at the surface of the wall are transferred to a stable zone behind the retained mass through tie-backs (Fig. 3.1c). Alternatively, an anchored wall can be an element wall, a wall made up of several individual components, each anchored with a tie-back (Fig. 3.1d). A cantilevered retaining wall with vertical anchors acting through the footing and providing resistance to overturning can also be considered to be a type of rock-anchored wall.

3.3 Principles of Rock Nailing

Rock nailing refers to a procedure of installing reinforcing elements into a rock mass exposed by an excavation in order to form an internally supported structure. Rock nailing by TxDOT is generally applied as an extension of soil nailing techniques to the support of rock excavations. In soil nailing construction, reinforcement elements are installed in a systematic pattern as the excavation progresses, with each row of elements being installed into natural material before the next increment of excavation (Fig. 3.2). The elements are placed in a drilled hole, typically angled about 10° to 15° below horizontal, and secured with grout. Pneumatically-applied concrete (shotcrete) is used to give additional face-support to the retained mass, bridging between the nails. In addition, for permanent nailed structures, reinforced concrete facing panels are added to the face of the nailed wall.

Soil nail patterns and lengths are often chosen from experience, but some theoretical design procedures have been developed (Elias and Juran, 1991). Stocker and Riedinger (1990) report that German experiments have found that a spacing of less than 1.5 m is appropriate for soil. Mitchell and Villet (1987) report on designs used on various nailed walls in France. The spacings on these projects varied from 1.0 to 2.0 m vertically and 1.0 to 3.0 m horizontally.

A rock mechanics approach to nailing is typically focused on the behavior of discontinuities within the rock mass. Douglas and Arthur (1983) described the action of rock reinforcement as (1) preventing the detachment of loose blocks, (2) increasing the shear resistance along discontinuities, and (3) increasing the interlocking of rock blocks. Therefore, in rock, untensioned reinforcement is perceived to perform more of a knitting function, where reinforcement reactions are concentrated at discontinuities present in the rock mass.

3.4 <u>Grouted Anchorage Materials</u>

Although many types of reinforcing elements have been developed in the mining and civil construction industries, the most common type of reinforcement used for rock-slope reinforcement is the fully grouted type. Other types of reinforcement are discussed by Whitt (1995).

3.4.1 Grout

Grouted anchorages transfer tensile and shear loads through cement or resin grout placed in the annulus of the borehole around the element. The grout transfers the applied load to the rock primarily through mechanical interlock. However, chemical bond and friction are also involved in load transfer.

The grout used for grouted anchorages is usually either Portland cement or resin. Cement grout is usually pumped or poured in a liquid state, although cartridges are also available so the materials can be mixed in place (Douglas and Arthur, 1983). Resin grouts are generally either polyester or epoxy. Polyester resin grouts are quicker setting and often less expensive, while epoxy resins are stronger and more versatile. Resin grout can be pumped in liquid form as with cement grout, but because of safety concerns and convenience it is usually placed in cartridges. Resin ingredients, especially in cartridge form, have a limited shelf life, because some of the ingredients break down over time.

Cartridges for resin and cement grouts allow the material to be placed in the borehole in a dry form because the cartridges keep the active ingredients separated. Grout cartridges are placed in a borehole before installation of the reinforcing element. When the element is installed, it is rotated, shredding the plastic or glass cartridge casing and mixing the grout ingredients.

Grouted anchorages are the most appropriate anchorage type for rock slope reinforcement applications and the most commonly used. Therefore, grouted anchorages will be the anchor type most extensively discussed in this report.

3.4.2 Reinforcing Element Materials

The materials used for reinforcing elements are wires, cables, and bars. Wires and cables (also called strands - a member made up of bundled wires) are made from steel and are generally used in rock reinforcement only where very high capacity anchors are required. Bars are usually made from mild steel or high-carbon steel, although stainless steel and other alloys (like chrome-nickel steel for salt water and acid resistance) have been used. The bars can be smooth, deformed (rebar), or threaded. Deformed bars are the same as those used to reinforce concrete. Threaded bars have a thread pattern cold-rolled on the surface either over the full length of the bar (continuously threaded) or at one or both ends. Continuously threaded bars are useful on projects where different length bars are used because they can be cut to any length, while bars threaded only on the end must be specially ordered. Properties of continuously-threaded bars supplied by two sources, Dywidag-Systems International and Williams Form Engineering Corp., are presented in Table 3.1.

Bars are normally solid but, for easier grouting, hollow bars have been developed which permit grout to be injected through the hollow center of the bar. Williams Form Engineering Corp. (1992) advertises a 30 mm external diameter hollow core continuously-threaded bar with an 8.3 mm inside diameter core hole. The manufacturer states that this has an advantage over the use of grout tubes and solid bars, because grout tubes may not always reach the bottom of the borehole or they can be damaged during installation, both of which would prevent full grouting.

Fiberglass bars have been developed as an alternative to steel. Fiberglass bars have a similar capacity to steel bars of equivalent size, but are much more flexible (Douglas and Arthur, 1983). Dywidag-Systems International manufactures fiberglass bars (called Dywidur bars) with nominal diameters of 22 and 25 mm, a tensile strength of 950 MPa and a Young's modulus of 50,000 MPa (Dywidag, 1993b).

Some advantages of fiberglass reinforcing bars include:

1. The low stiffness allows them to be installed where space is confined;
2. Fiberglass bars are lightweight and therefore easier to transport and handle than steel bars;

3. Unlike steel, fiberglass is resistant to corrosion and does not conduct electricity;
4. Fiberglass bars are useful in corrosive environments;
5. Fiberglass bars do not disrupt electro-magnetic fields near sensitive electro-magnetic equipment; and
6. Fiberglass bars can be more easily cut through than steel bars where re-excavation may be necessary;

Disadvantages of fiberglass bars include:

1. Fiberglass bars typically cost more than steel bars; and
2. Fiberglass bars allow more deformation than similarly dimensioned steel bars because the Young's modulus of fiberglass is about one-fourth that for steel.

3.4.3 Element Heads

The element head is the part of the reinforcing element where loads are transferred from the element to the rock at the face of the excavation, as well as to any surface support system that may be used, such as shotcrete and wire mesh. This transfer of load allows the surface rock and support system to be integrated with the rock mass, so that smaller loose blocks cannot fall out and surface deformations are controlled.

Where the reinforcing elements used are bars, the most common design at the element head is a nut, washers and a face plate. A nut is screwed onto the threaded end of the element and bears on a face plate, which distributes the load to the rock surface. Washers are used between the nut and plate to provide more efficient load transfer. Douglas and Arthur (1983) recommend using two beveled washers, or a hemispherical washer in a shaped setting on the plate, to insure uniform load transfer. The washer immediately under the nut should be made of hardened steel to prevent damage to the washer during tensioning.

There are several types of face plates that have been used. Flat plates are often used and can be square, circular or triangular in shape. Table 3.2 includes typical plate sizes (diameter or length of a side) and thickness for different working element loads. In order to prevent deformations of the plate under high element loads, either the thickness of the plate can be increased or two plates can be used.

The disadvantage of a flat plate is that it bears on the rock at only a few points near the center of the plate. If element loads are high, the rock can be crushed at these points. As an alternative where loads or deformations are expected to be high, a deformed plate can be used. Figure 3.4 illustrates two commonly used deformed plates, the domed and triangular bell-shaped plates. Deformed plates contact the rock surface closer to the edges of the plate, reducing point loads on the rock. Also, the plate deforms when load is applied giving a positive visual verification of tensioning.

3.4.4 Corrosion Protection

Corrosion protection is an important part of choosing the proper reinforcing element materials. The most important parameters of the reinforced material (rock or soil) influencing corrosion are the content of dissolved salts, pH, porosity, and degree of saturation. Environmental conditions that cause the highest corrosion rates are a high content of total dissolved salts, high chloride concentration (> 200 ppm), high sulfate content (> 1000 ppm), and acidic or alkaline pH conditions (Mitchell and Villet, 1987).

For grouted reinforcing elements, the grout itself (primary and secondary) provides a measure of protection. However, since the grout often cracks, possibly allowing water to reach the member and cause corrosion, additional protection is needed. Common protection methods include epoxy coatings (limited to deformed bars for adequate bonding) and galvanized or plated bars (Douglas and Arthur, 1983). A minimum grout thickness of 37 mm and deformed reinforcing bars with electrostatically applied epoxy to a minimum thickness of 3.5 mm are recommended by Elias and Juran (1990).

Table 3.1. Properties of Continuously Threaded Bars
(after Dywidag, 1993a and b; Williams, 1992).

Manufacturer	Yield Stress MPa	Ultimate Stress MPa	Available Nominal Diam. mm	
Dywidag	414	620	19.1, 25.4, 37.8, 44.5,	22.2, 28.6, 34.9, 57.2.
	517	689	22.2, 44.5, 63.5.	25.4, 57.2,
	881	1034	26.0, 36.0.	32.0,
	937	1103	26.0, 36.0.	32.0,
Williams	881	1034	26.0, 36.0,	32.0, 45.0.

Table 3.2. Typical Faceplate Dimensions
(after Douglas and Arthur, 1983).

Working kN	Surface Area	Thickness mm
80	125 to 150	7
150	150 to 200	10
300	200 to 250	12

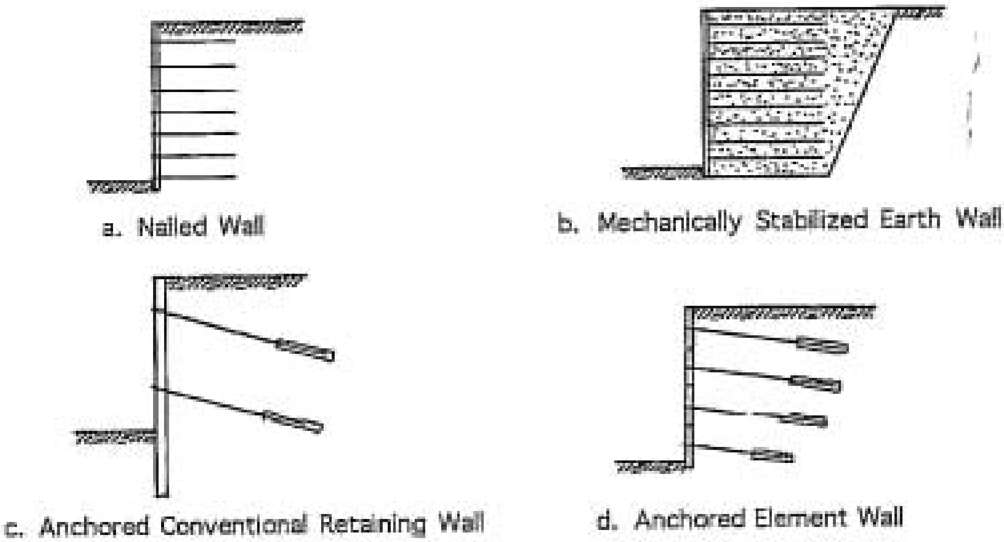


Figure 3.1. Contrasting Retaining Systems (after Stocker and Riedinger, 1990).

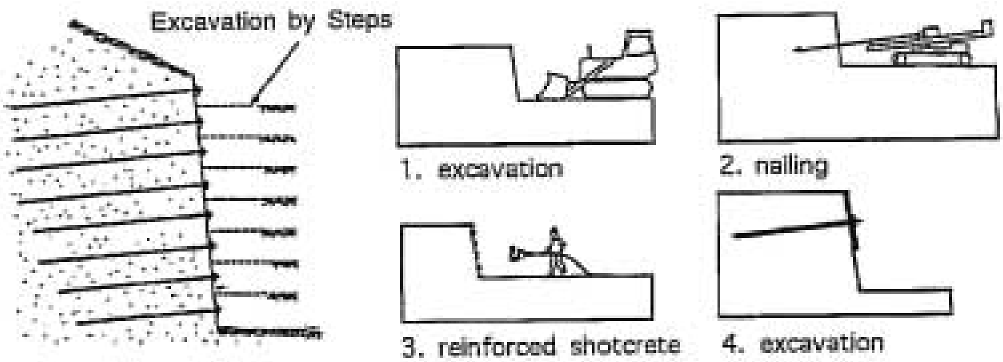


Figure 3.2. Soil-Nailing Construction Process (from Mitchell and Villet, 1987).

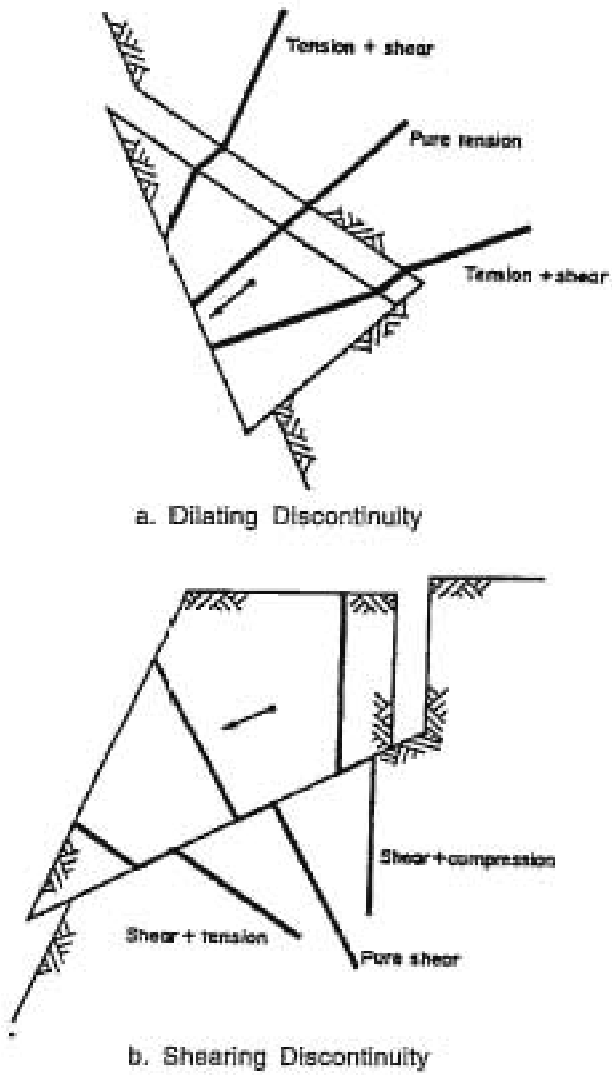


Fig. 3.3. Reinforcement Behavior at a Discontinuity
(from Douglas and Arthur, 1983).

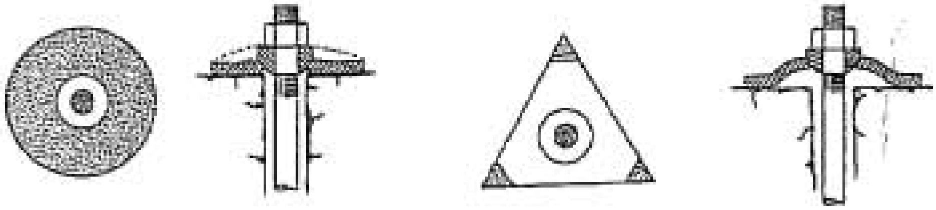


Fig. 3.4. Common Deformed Shapes of Bearing Plates (from Stillborg, 1986).

CHAPTER 4. FIELD AND LABORATORY TESTING PROGRAM

4.1 Introduction

This chapter describes the field and laboratory testing program that was implemented to evaluate the properties and performance of existing road-cut exposures in Texas. All TxDOT districts with rock slopes were sent a questionnaire developed by the project team (Galvan, 1995) to identify areas and sites where rock cut slope stability was an important issue. Based on the responses, 53 sites were selected for investigation. Table 4.1 summarizes the sites by district and geologic formation.

A field reconnaissance study was conducted at each of the 53 sites. Based on these results, three case-study sites with rock-nail supported slopes were selected for further investigation. These sites were respectively located in the three major geologic formations studied, the Austin Group, Edwards Formation and Glen Rose Formation. Two rock-core borings were drilled at each of the case-study sites. Finally, laboratory tests were conducted on grab samples obtained from various sites and on core samples obtained from the case-study sites. Details for the field and laboratory testing program are presented in this chapter, and the results are summarized in Appendices A (field reconnaissance), B (maintenance information), C (boring logs) and D (laboratory test results). The results will be analyzed in Chapters 5 through 7.

4.2 Field Reconnaissance

4.2.1 Introduction

Field reconnaissance studies of particular road-cut exposures were made in the Dallas, Fort Worth, Austin, San Antonio, and El Paso Districts of TxDOT. Each of these districts responded to a questionnaire developed by the project team (Galvan, 1995) to identify areas where rock cut slope stability was an important issue to TxDOT. During the period from March 1994 to July 1995, a total of 53 detailed field reconnaissance studies were made on cut slopes in these districts.

4.2.2 Data Collection Forms

Four forms were developed for data collection at each field exposure. The first form (Fig. 4.1) contains basic information about the site. The second form summarizes the engineering geologic parameters (Fig. 4.2). The third form (Fig 4.3) allows the investigator to quantify the effect of discontinuities by conducting horizontal scanlines over a known distance and describing in detail each discontinuity encountered. The strike and dip relative to the cut face is recorded along with the joint condition and persistence. A space is provided at the bottom of this page for the "apparent spacing" between joints of a given joint set and also the "true spacing" which is the number used in the empirical classification schemes. The apparent spacing is the distance between joint traces along the scanline, whereas the true spacing is the perpendicular distance between joints and is calculated by multiplying the apparent spacing by the sine of the angle between the strikes of the cut face and the joint. The final form (Fig. 4.4) is for vertical scanlines, RQD determination, and fracture frequency. A quick reference sketch is also provided to help the investigator determine the approximate slope height or height to any point on the slope if direct measurement is not feasible.

4.2.3 Site Descriptions

Sites in the Austin, Dallas, Fort Worth, and San Antonio districts were studied in detail using the developed data collection forms. Table 4.1 summarizes the 53 sites by district, geologic formation, and primary investigator. Locations and general information about the sites are presented in Tables 4.2 through 4.4, and the complete data collection forms for each site are included in Appendix A.

4.2.4 Maintenance Information

Maintenance information, which provides an indication of historical performance of the cut slopes, was also collected. The TxDOT maintenance foreman of each section where cuts were studied was contacted to gather pertinent maintenance information. Standard information was requested for each site including the following:

- Age of cut;
- Method of excavation;
- Frequency and type of repair or cleanup;
- Type and size range of debris;
- Frequency of and amount of debris entering roadway; and
- Any pertinent additional comments.

It was possible to obtain the above information for all but one site, the Lake Georgetown Spillway in Williamson County, which is under jurisdiction of the Army Corps of Engineers. The results of the maintenance surveys are presented in Appendix B.

4.3 Subsurface Exploration

4.3.1 Background

Geotechnical core borings were drilled at three of the sites selected during the field reconnaissance phase of the project. The objective was to supplement field observations with data from core such as RQD, uniaxial compressive strength, bed thickness and discontinuity information, and to retrieve samples for laboratory testing. Drilling operations were conducted in accordance with standard practice in Texas. Hence, the core quality was comparable to that expected if TxDOT conducted the work or contracted out to local private firms. Currently, the Austin District contracts their core drilling work to local consultants, while the San Antonio District possesses its own drilling equipment and crews. In accordance with accepted practices, drilling was performed with a double-tube core barrel equipped with an NX-size (50 mm) diamond insert cutting bit for the Glen Rose and Edwards Formations, or a tungsten-carbide bit for Austin Chalk. The same crew, equipment, and rig was used for all coring to attempt to minimize the variability in core quality that can occur with different crews and equipment. The care of the driller is particularly important for softer rocks like the ones studied for this project.

4.3.2 Case-Study Sites with Rock-Nailed Slopes

Three sites located in the three main geologic formations studied (Austin, Glen Rose, and Edwards) were selected for core drilling (Tables 4.2, 4.3 and 4.4). Two borings were drilled at each site to a depth of approximately 12 m. All three sites have near vertical cuts. At each site, a portion of the rock slope is supported by rock nails (e.g., at a bridge abutment) while the remainder is not supported. An attempt was made to locate the borings as close to the edge of the slope crest as possible. The field boring logs are included in Appendix C. A summary of pertinent site features is presented in Table 4.5, and plan and cross-section views of the sites are shown on Figs. 4.5 to 4.7.

Site 1: The first case-study site is a 10.5-m high cut in the Glen Rose Formation along RM 620 near Mansfield Dam (Lake Travis), west of Austin (Fig. 4.5). The cut on the west side of the road is unsupported, while that on the east side is supported with rock nails. One boring was drilled above the unsupported cut and one above the rock-nail wall. Below the top 2 to 3 m of weathered rock, core recovery was 100% and RQD's ranged from 65 to 100 with an average of 84.

Site 2: The second case-study site is a 6-m high cut along the westbound frontage road of IH-30 at Hampton Road in Dallas (Fig. 4.6). The Austin Chalk outcrops at this site, however the Eagle Ford Formation (shale) was encountered in the borings below the depth of the cut. The cut is supported with rock nails beneath a bridge abutment and unsupported elsewhere. Core recovery varied from 79 to 100% and RQD's ranged from 8 to 100. Boring No. 1 was started with a carbide bit and RQD's of consecutive core runs were 0, 85, 10, and 8. At a depth of 6 m, the bit was changed to a diamond bit and RQD's then ranged from 56 to 100. The average RQD for the two borings, neglecting the portion drilled with the carbide bit, was 87.5.

Site 3 The third case-study site is a 5.5 to 8-m high cut located along Loop 1604 at the Bitters Road underpass in San Antonio (Fig. 4.7). Vertical cuts were made along Loop 1604 to depress the road below Bitters Road. Rock nailed walls were installed under both bridge abutments. Outside of the bridge area, the cuts are left unprotected. One boring was drilled on either side of Loop 1604 above the cut, west of the bridge. This site is located in an extensively solutioned portion of the Edwards Formation. Drilling at this site was complicated due to the very blocky nature of the rock. Core recovery ranged from 20 to 100% and RQD's ranged from 0 to 42 with an average of less than 15.

4.4 Laboratory Testing

Laboratory tests were performed on samples from the road-cut sites. The objectives of the testing program were (1) to quantify and compare rock properties from different formations, sites, and layers at a site and (2) to correlate laboratory-measured properties with observed performance. Two types of samples were collected: grab samples taken from the face of the slope and core samples from the case study sites. The following tests were performed: water content (ASTM D2216-90), calcium carbonate content (ASTM D4373-84), slake durability (ASTM D 4644-87), splitting tensile (Brazilian) strength (ASTM D 3967-92), unconfined (uniaxial) compressive strength (ASTM D 2938-86), moduli of elasticity in uniaxial compression (ASTM D 3148-93), ultrasonic determination of elastic constants (ASTM D 2845-90), and Moh's hardness (Institution of Civil Engineers, 1976). The laboratory test results are presented in Appendix D.

Table 4.1. Breakdown of Roadway-Cut Sites Observed

TxDot District	Geologic Formation and Number of Sites	Field Investigator
Austin	Glen Rose: 12 sites Edwards: 2 sites	Young, Galvan
Dallas	Austin Chalk: 5 sites	Galvan
Ft. Worth	Winchell/Wolf: 1 site Comanche Peak: 1 site	Galvan
San Antonio	Glen Rose: 19 sites Edwards: 21 sites	Young

Table 4.2. Austin District Sites

Site Code	Location	County	Geologic Formation	H (m)	L (m)	Layback Angle (°)	Method of Support
360-1	Loop 360, N. of RM 2222	Travis	Kgr	22.5[b]	300	10	None
360-2	Loop 360 at RM 2244	Travis	Ked, Kwa, Kgr	24.3[b]	390	10-12	None
360-3	Loop 360, 1.6 km N. of Wild Basin Road	Travis	Kgr	6.6	117	5	None
620-1*	RM 620 at Mansfield Dam	Travis	Kgr	10.5	279	12-15	Rock Nails/ None
620-2	RM 620 So. of Lakeway	Travis	Kgr	9[b]	228	18-20	None
2244-1	RM 2244 at Crystal Creek Road	Travis	Kgr	6.6	111	12	None
2244-2	RM 2244 at Addie Roy Road	Travis	Kgr	5.4	165	15	None
SWP-1	Southwest Parkway, east of US 71	Travis	Kgr	7.5	330	12	None
SRR-1	Steiner Ranch Road at Quinlan Park Road	Travis	Kgr	9	168	8-10	None
Au-1	RM 2222 between Loop 360 and Mopac	Travis	Kgr	15	>1 km	<15	None
Au-2	RM 2222 at Loop 360 drainage channel	Travis	Kgr	7.5	45	5	None
Au-3	Lake Georgetown spillway	Williamson	Ked	14	1.6 km	30	None
Au-4	US 87 north of Mason	Mason	Ked	12	110	10-15	None

Notes: * indicates case study site, [b] indicates benched cut, Kgr = Glen Rose Fm., Ked = Edwards Fm., Kwa = Walnut Fm., H = maximum height, L = total length of slope

Table 4.3. Dallas and Fort Worth District Sites

Site Code	Location	District	County	Geologic Formation	H (m)	L (m)	Layback Angle (°)	Method of Support
D-1	Loop 303 ea. of Loop 12	Dallas	Dallas	Austin Chalk	4.5	61	0 to 40	None
D-2*	IH 30 at Hampton Road	Dallas	Dallas	Austin Chalk	6	120	varies	Rock Nails (Abutment)
D-3	IH 30 at Loop 12	Dallas	Dallas	Austin Chalk	11	150	40	None
D-4	FM 1382 , Cedar Hill	Dallas	Dallas	Austin Chalk	11	60	15	None
D-5	New Clark Rd. at FM 1382	Dallas	Dallas	Austin Chalk	12	73	12	None
FW-1	US 377 between Granbury and Cresson	Ft. Worth	Hood	Comanche Peak	5.5	156	13	None
FW-1	SH 16 west of SH 337	Ft Worth	Palo Pinto	Winchell, Wolf Mt.	20	500	15	None

Notes: * indicates case study site, [b] indicates benched cut, Kgr = Glen Rose Fm., Ked = Edwards Fm., Kwa = Walnut Fm., H = maximum height, L = total length of slope

Table 4.4. San Antonio District Sites

Site Code	Location	County	Geologic Formation	H (m)	L (m)	Layback Angle (°)	Method of Support
281-1	US 281, S. of Cibolo Creek	Comal	Kgr	6	276	12	None
281-2	US 281 at Belverde Estates	Comal	Kgr	7.5	156	15	None
281-3	US 281 just S. of SH 46	Comal	Kgr	10.5	375	15	None
281-4	US 281, 7.9 km S. of Guadalupe River	Comal	Kgr	4.5	189	12	None
281-5	US 281 just N. of 281-2	Comal	Kgr	9	330	12	None
1376-1	FM 1376 N. of Boerne	Kendall	Kgr	13.5	138	10-15	None
1376-2	FM 1376 S. of FM 473	Kendall	Kgr	9	317	20-25	None
1-10-5	IH-10 near FM 289	Kendall	Kgr	7.5	137	0	None
2722-1	FM 2722 btwn. FM 2673 and SH 46	Comal	Kgr	18.3	108	0	None
2673-1	FM 2673 at FM 2722	Comal	Kgr	7.5	180	0 to 20	None
3159-1	FM 3159 N. of SH 46	Comal	Ked	6	360	5	None
I-10-1	0.8 km E. of SH 16	Kerr	Ked/Kgr	22[b]	300	10	None
I-10-2	2.4 km E. of SH 16	Kerr	Ked	7.5	216	12	None
I-10-3	IH 10 at Cypress Creek	Kerr	Ked/Kgr	21[b]	360	varies	None
I-10-4	IH 10 just west of Cypress Creek	Kerr	Ked/Kgr	16.5	300	10-12	None
I-10-6	IH 10, 1.6 km W. of SH 16	Kerr	Ked	21[b]	105	6	None
I-10-7	IH 10, 1.6 km W. of FM 783	Kerr	Ked	5.5	180	5	None
I-10-8	IH 10 just E. of FM 1338	Kerr	Ked/Kgr	24	308	10	None
I-10-9	IH 10 in Gillespie Co.	Gillespie	Ked	7.5	360	0	None
41-1	SH 41 at SH 27	Kerr	Ked	10.5	300	0	None
187-1	FM 187 N. of Lost Maples State Park	Bandera	Ked	15	780	15	None
337-1	FM 337 at Mill Creek	Bandera	Ked/Kgr	18	195	15	None
337-2	FM 337, top of Mill Creek Pass	Bandera	Ked	7.5	190	15-20	None
470-1	FM 470, Tarpley Pass	Bandera	Kgr	16.5	293	30+	None
211-1	SH 211N. of FM 471	Medina	Ked	10[b]	300	16	None
211-2	SH 211 N., of Bexar Co. line.	Bexar	Ked	17[b]	550	15	None
211-3	SH 211 S. of SH 16	Bexar	Ked	30[b]	420	10-15	None
1283-1	FM 1283 at CR 270	Medina	Kgr	15	225	12	None
1283-2	FM 1283, 1.4 km S. of Park Road 37	Medina	Ked	10.5	170	10-12	None
173-1	FM 173 S. of Bandera- Medina Co. line	Medina	Ked	15	330	10-20	None
S-1*	Loop 1604 at Bitters Road	Bexar	Ked	8	>2 km	15	Rock Nails (Abutment)
S-2*	Loop 1604 at Gold Canyon Road	Bexar	Ked	5.5	400	15	Rock Nails (Abutment)

Notes: * indicates case study site, [b] indicates benched cut, Kgr = Glen Rose Fm., Ked = Edwards Fm., Kwa = Walnut Fm., H = maximum height, L = total length of slope

Table 4.5 Summary of Case-Study Sites with Rock-Nailed Slopes

Site	R.M. 620 West of Mansfield Dam	I.H. 30 and Hampton Rd.	Loop 1604 and Bitters Rd.
Geologic Formation	Glen Rose Limestone	Austin Chalk	Edwards Limestone
Age of Wall	6 mo	5 years	5 years
Method of Excavation	Ripping	Not Available	Blasting, Pre-Split
Height (m)	10	6.1	7
Face Strike	N 85° E	N 90°E	N 42°E
Layback	0°	Varies from 0° to 15°	15°
Nail Type	Grade 60 Dywidag *threadbar, epoxy coated*	Grade 60 Dywidag *threadbar, epoxy coated*	Grade 60 Dywidag *threadbar, epoxy coated*
Nail Spacing (m)	1.5 H, 1.5 V	1.5 H, 1.5 V	1.5 H, 1.5 V
Nail Length (m)	7	4.5	6
Facing Type	100-mm gunite with 6x6 No. 6 WW mesh	100-mm gunite with 6x6 No. 6 WW mesh	100-mm gunite with 6x6 No. 6 WW mesh
Drainage	300-mm wide mat at 3 m on center	300-mm wide mat at 3 m on center	300-mm wide mat at 3 m on center
External Loads	2H:1V Backfill	Bridge Traffic	Bridge Traffic

TxDOT Rock Mass Field Description

Code: ______ Date: ____

Page __of__

Formation: ____________________

Location: ____________________

TxDOT District:

Elev.(ft)

Profile Sketch

N

Plan Sketch

General Exposure Description

Dimensions and Orientation:

Total Height (ft): ____________________

Lateral Extent (ft): ____________________

Benches: Height Width

L1 ____________

L2 ____________

L3 ____________

Face Orientation:

Strike/dip: ____________________

Catchment Description: ____________________

Artificial Support: ____________________

Method of Excavation (incl. effects): ____________________

Age of Exposure: ________ Vegetation Effects: ____________

Elev. (ft)

Elevation (ft) looking ___

Fig. 4.1. Field Form for General Exposure Description.

TxDOT Rock Mass Field Description

Date: ______
Page: ____ of ____
Code:: ______

Summary of Engineering Geologic Data

Joint Description Summary

Set #	Strike	Dip	Roughness	Separation/ Filling	Persistence	Weathering	Remarks

Other Structural

Feature	Strike	Dip	Condition	Persistence	Remarks

Occasional Random Joints? ______________________

Bedding Description: ______________________

Weathering/Erosion: ______________________

Form of Slope Failure/Degradation: ______________________

Debris: ______________________

Maintenance Record: ______________________

Available Geotechnical Data: ______________________

Fig. 4.2. Field Form for Summary of Engineering Geologic Data.

TxDOT Rock Mass Field Description

Date: ____
Code: ____

Scanline Descriptions

Horizontal Scanline Number: ____

Page: ___ of ___

Horizontal Location (locate on sketch):
Height above base of cut (ft): __________
If w/in one layer, layer thickness: __________________
Length of scanline ...__________
Strike of scanline __________

0+00 0+50 1+00

Scanline Sketch (include seepage locations)

Debris Description

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Condition
			+/-20	20-45	45-90	R/L	+/-20	20-45	45-90	R/L		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												

Set	Apparent spacing (#/scan length)	True Spacing (#/scan length)
1		
2		
3		
4		
5		

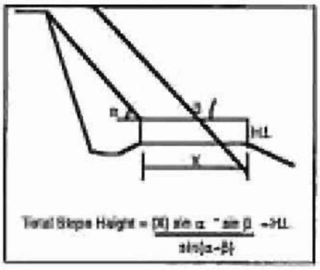
Fig. 4.3 Field Form for Scanline Descriptions.

TxDOT Rock Mass Field Description

Date: ________
Code: ________
Page: ___of___

Scanline Descriptions

Vertical Scanline Number: ____________
Scanline Location (show on sketch): ______________________________
Height of Scanline (ft): ____________
Length of Scanline(ft): ____________



Scanline Sketch

Photo No.	Description

Samples: ______________________________

Est. RQD: ______
Fracture Frequency: ______

Scanline Information:

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Cond'n
			+/-20	20-45	45-90	R/L	+/-20	20-45	45-90	R/L		
1												
2												
3												
4												
5												
6												
7												
8												
9												

Fig. 4.4 Field Form for Vertical Scanlines and RQD Estimate.

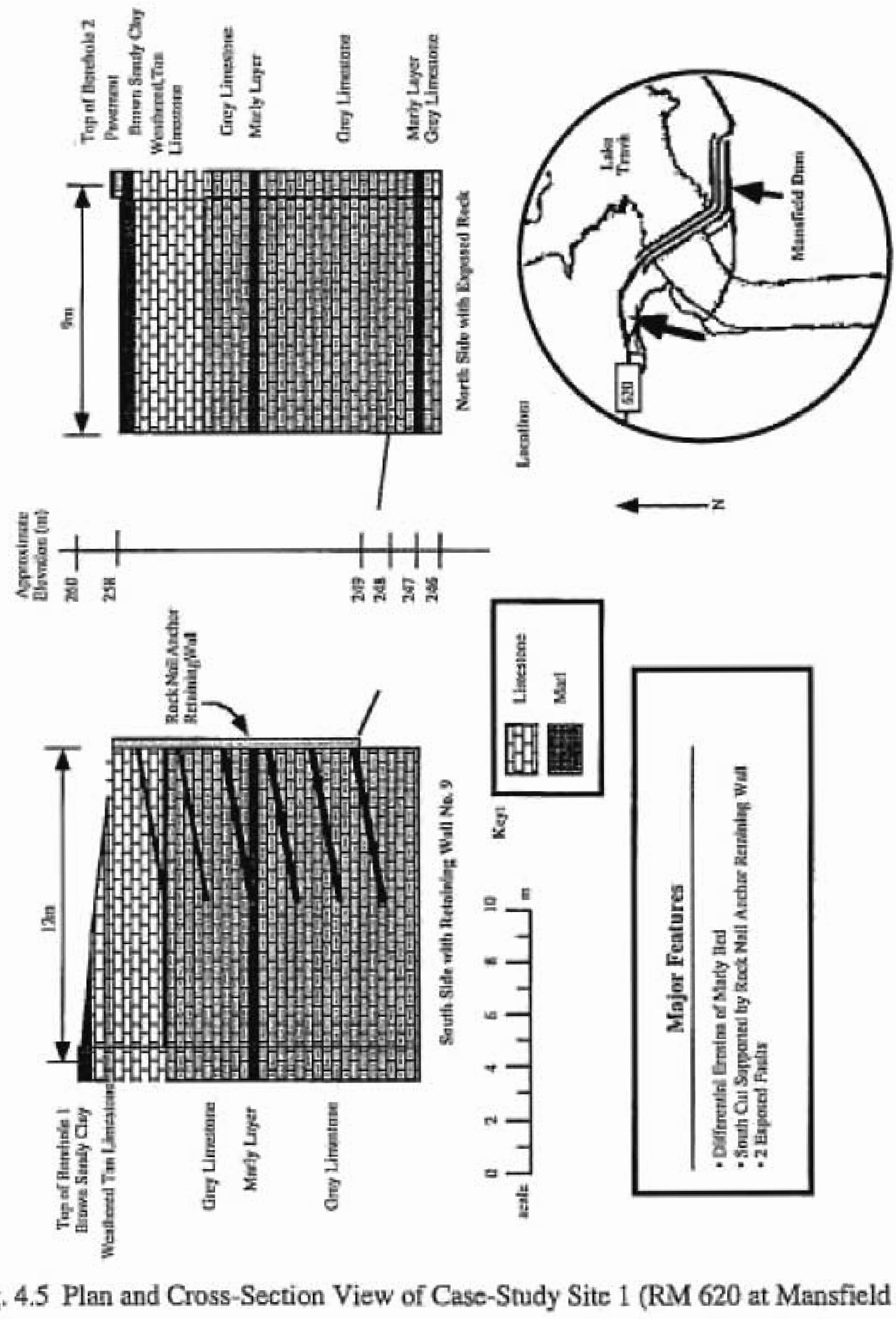


Fig. 4.5 Plan and Cross-Section View of Case-Study Site 1 (RM 620 at Mansfield Dam)

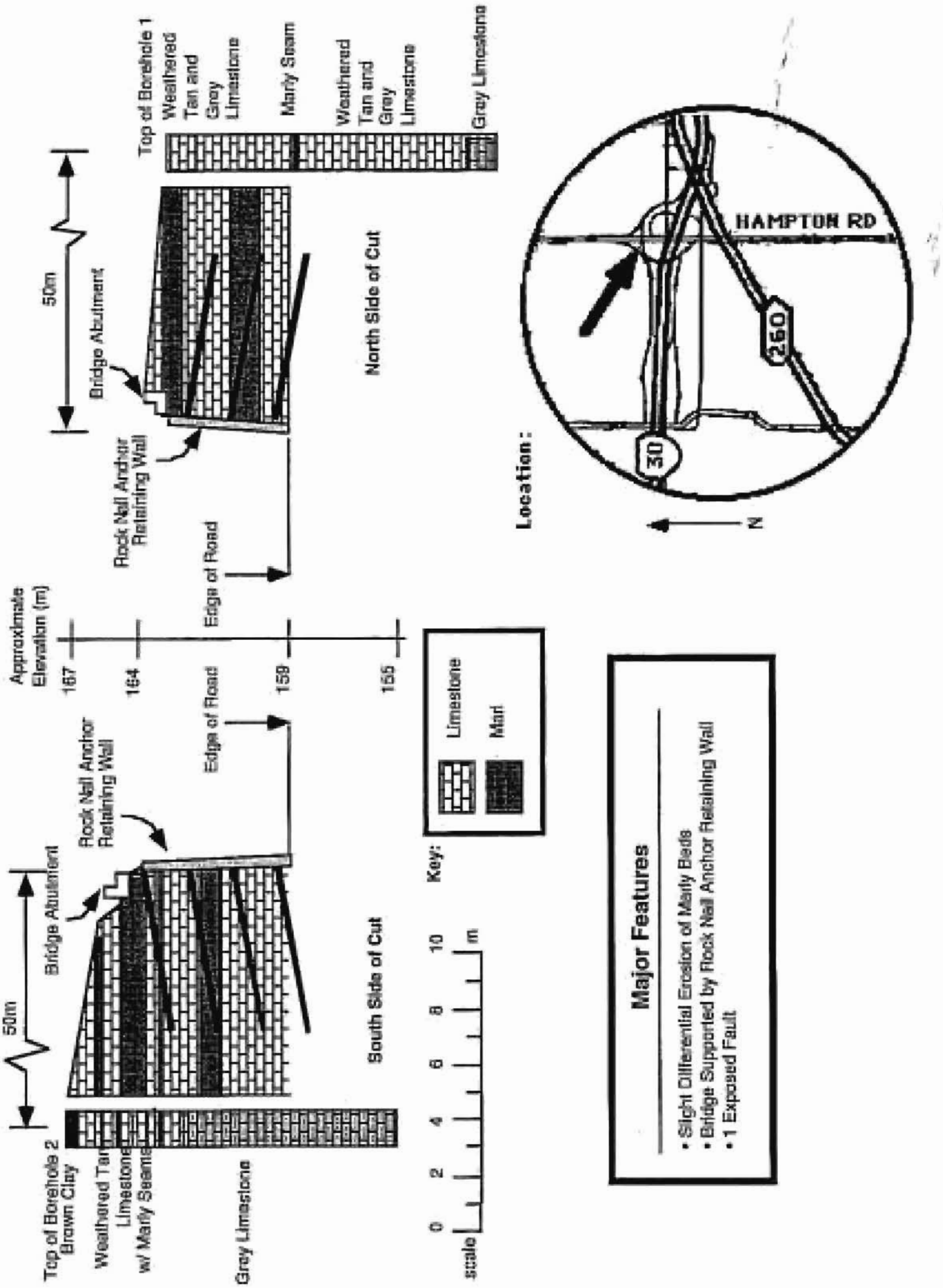


Fig. 4.6 Plan and Cross-Section View of Case-Study Site 2 (IH 30 at Hampton Road)

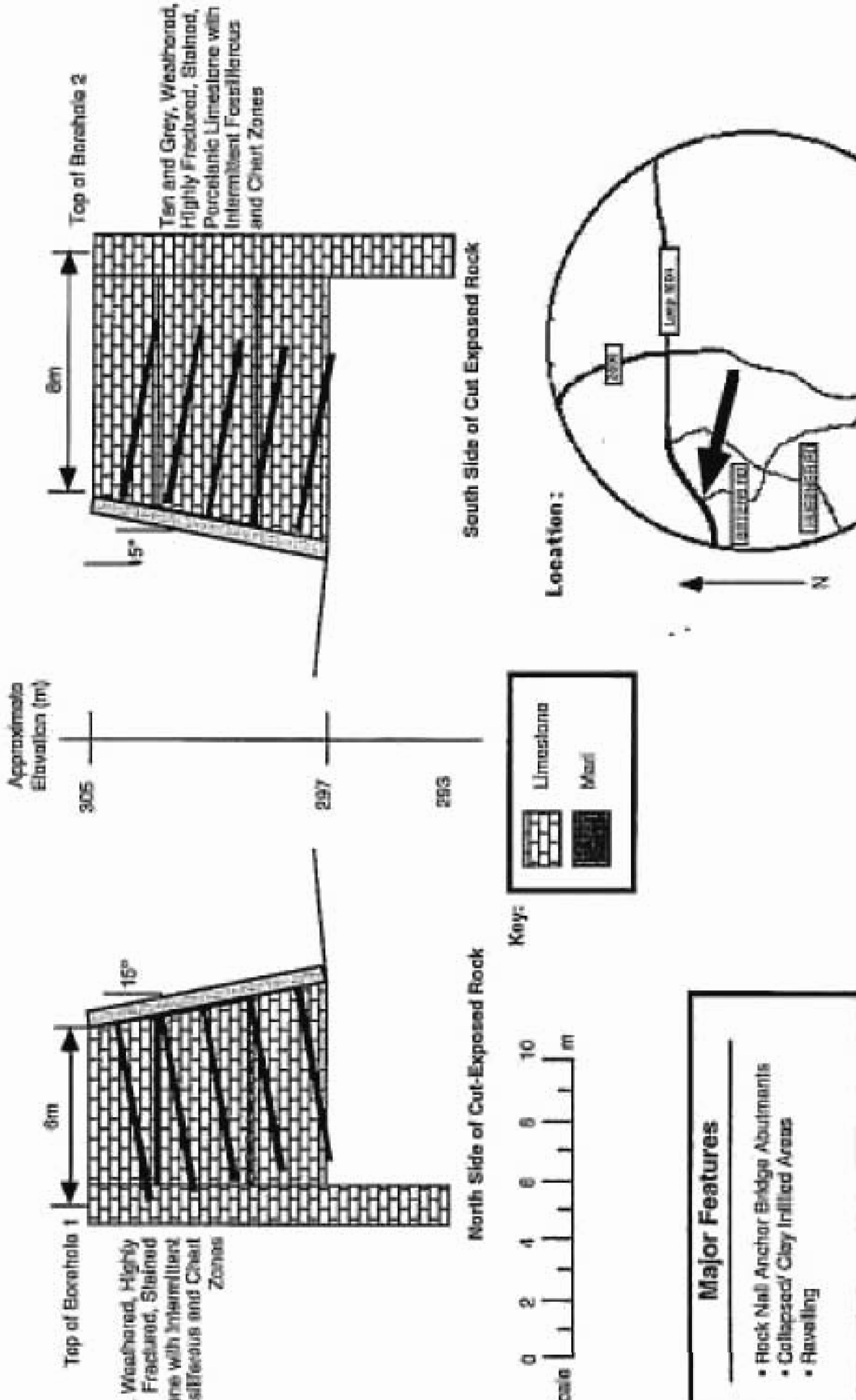


Fig. 4.7 Plan and Cross-Section View of Case-Study Site 3 (Loop 1604 at Bitters Road)

CHAPTER 5. PERFORMANCE OBSERVATIONS

5.1 Introduction

Performance of the study sites was based on visual observations by the authors as well as the maintenance history of the slopes as reported by TxDOT maintenance personnel. This chapter presents the results of the field observations and available maintenance information for each site, along with a discussion of rockfall potential and catchment adequacy. Several quantitative rating schemes are developed and applied to characterize slope performance: a stability rating, a maintenance rating, and a catchment adequacy rating.

5.2 Modes of Failure in Rock Slopes

A brief discussion of the modes of failure in rock slopes is necessary before describing the field observations which included the predominant observed failure or potential failure modes. The term "failure" is used in a broad sense to include all forms of degradation.

Planar: This mode of failure occurs in soft and hard rock when a through-going discontinuity or weak plane strikes at an acute angle to the slope face and daylights into the face. Failure occurs when the angle of inclination (dip) exceeds the shear strength along the plane. An example of planar failure is shown in Fig. 5.1.

Circular: Circular failures occur in soft or highly weathered rock along a circular surface. This mode of failure is identical to slope failures in cohesive soil.

Wedge: Wedge failures occur when two discontinuities, dipping toward the slope face, intersect. The scale of the failure is determined by the discontinuity spacing. An example of a wedge type failure is given in Fig. 5.2.

Block: Block failure occurs where relatively flat lying, low strength discontinuities are present. Excavation relieves lateral stress, and where layers of different stiffness are in contact, differential strains occur at the contact and the shear strength along this surface is reduced. Lateral movements that occur as a result of stress relief tend to open joints or create steep tension cracks behind the slope face (Brawner, 1994). The resulting opening is now susceptible to increased pressure from build-up of precipitation which can create forces large enough to move the block.

Toppling: Toppling failure is not very common in flat lying sedimentary rocks, like those studied for this project. It occurs when there are closely spaced, steep discontinuities oriented in the same direction as the slope face. Therefore, this type of failure is most common in steeply dipping sedimentary and metamorphic rocks such as slates, shales, and siltstones.

Toppling is possible in flat lying rock if there are other closely spaced, steeply dipping discontinuites that are oriented in the same direction as the slope face.

Raveling: Raveling can be thought of as similar to spalling of concrete where fragments fall from the face. Raveling can be caused by hydrostatic pressure in joints and cracks, ice-wedging, differential weathering or erosion along faults or shear zones, weakening of the rock due to climatic variations, and root wedging (Brawner, 1994). The presence of closely spaced, bed-confined joints increases the likelihood of raveling, although their mere presence does not cause the failure. Raveling was the most common type of failure observed during this project and at least some degree of raveling was present on almost every slope observed. An example of raveling is shown on Fig. 5.3.

Differential Erosion: A specific type of raveling occurs due to differential erosion, in which softer, more erodible layers weather to leave cantilevers of more resistant layers. The loss of support causes the overlying resistive layer to fail in tension after the tensile capacity of the rock is exceeded. An example of this type of failure is shown in Fig. 5.4.

5.3 Field Observations

One of the primary objectives of the field reconnaissance was to evaluate, as least qualitatively, the performance of the slope, by noting information such as: type of slope failure or degradation, type and size of debris, catchment description, and presence and effect of vegetation. The field data sheets are contained in Appendix A. The type of failure and relative scale (local/global) for each of the sites are given in Tables 5.1 through 5.3. The distinction between "local" and "global" in the context of this report is that local failure is considered anything less than the full slope or bench height (in the case of benched cuts), and global denotes a failure that extends the full height of the slope or bench.

5.4 Visual Stability Rating

During the field observations, a subjective visual assessment of stability was quantified using a the Visual Stability Rating (VSR). This rating was evaluated by estimating the percentage of the original, excavated slope face remaining at the time of the field reconnaissance. The categorization scheme for VSR is presented in Table 5.4. The maximum VSR value of 4 corresponds to the best performance, while the minimum value of 0 corresponds to the poorest performance. Identification of the original face was straightforward in most instances because the majority of cuts were excavated by pre-splitting. This procedure leaves half-casts as evidence of the shot holes used for explosives along the excavated face. In the small number of cases where the cut was not presplit or where there was no evidence of pre-splitting, a subjective estimate of the original slope face was made. Sites in the Edwards and Glen Rose Formations were assigned VSR values (Tables 5.1 and 5.3); insufficient information precluded the use of this measure for sites in the Austin Chalk.

5.5 Maintenance Information

The TxDOT maintenance foreman for each maintenance section in which cuts were studied was contacted to gather historical performance information and maintenance requirements of each site. This information allows a comparison between sites with different conditions and possibly some general characterizations that will help predict the performance of future cut slopes. The results of the maintenance surveys are given in Appendix B. One performance measure used to compare different slopes was based on maintenance frequency. The classification scheme given in Table 5.5 was used to summarize the maintenance data based on frequency. The maximum MR value of 3 corresponds to the best performance (i.e., minimal maintenance required), while the minimum value of 0 corresponds to the poorest performance. This rating scheme was developed to characterize performance of slopes experiencing "local" failures or degradation (e.g., raveling, differential erosion, and some wedge failures), and is based on the maintenance frequency. It is not applicable to overall, global type failures. The Maintenance Ratings are summarized in Tables 5.1 through 5.3.

5.6 Characteristics of Each Formation

Only the Edwards, Glen Rose, and Austin Chalk were observed at a sufficient number of sites to characterize the performance of the formation. Therefore, only those three are discussed here.

5.6.1 Glen Rose Formation

Based on the sites observed, the Glen Rose is massive, with widely spaced joints and the performance is generally not controlled by kinematic behavior along joints. A total of 28 sites in the Glen Rose were studied. Raveling, to varying degrees, was present on every slope observed. Differential erosion resulting in cantilevered block fallout was observed on 15 of the 28 slopes (54%) and depended on whether softer, marly beds were present in the slope stratigraphy. Wedge failure along intersecting discontinuities was only observed at 3 of the 28 sites (11%) and planar failure only observed at 2 sites (7%). The planar failures occurred along faults that happened to strike at about 20 degrees from the slope face at two sites in an area of Comal County where faults are mapped (BEG, 1983). Toppling failure was observed at one site (1376-2) in Kendall County. This was the only site observed in the Glen Rose with closely spaced, near vertical joints, and at this site the joint strike was within 15 degrees of the strike of the slope face.

5.6.2 Austin Chalk

Five sites were observed in detail in the Austin Chalk Formation. All 5 sites exhibited raveling to some degree and 3 of the 5 (60%) exhibited block fall raveling due to differential erosion. Based on the very limited number of sites, a reasonable conclusion would be that the Austin Chalk, like the Glen Rose, exhibits local type raveling failure and is not controlled by persistent discontinuities which may produce wedge, planar, or block failure. Allen and Flanigan (1986) noted that small gravity or normal faults are common in the Austin Chalk. Certainly if such discontinuities were present at the site of a cut slope they could quite possibly trigger large scale planar or wedge failures depending primarily on their orientations and dip angle. More sites would need to be observed to enable characterization of cut slopes in the Austin Chalk.

5.6.3 Edwards Formation

Like the Glen Rose, the Edwards is generally massive with infrequent, widely spaced discontinuities. A total of 23 sites in the Edwards Formation were studied and all but one site exhibited at least minor raveling. Differential erosion was only observed at six of the 23 sites (26%). At four of these sites, the differential erosion occurred at the contact between the Ft. Terret member of the Edwards Formation and the Glen Rose Formation. The Glen Rose is softer than the Edwards and is more susceptible to erosion. When the softer Glen Rose erodes back from the slope face, a cantilevered situation occurs and blocks of the massive Ft. Terret fail in tension. Minor, local wedge failures were only observed at one site. Large scale, global toppling was observed at one site (337-1) in Bandera County along FM 337. Persistent joints striking at an acute angle to the slope face and dipping slightly toward the face opened gradually over time, and scale blasting was conducted to remove the large blocks prior to seemingly imminent failure. Since the blasting operations, more joints have opened (as much as 0.3 m aperture) to the point where blasting is again being considered by TxDOT to remove the large blocks before they break free and impact the roadway. This particular site has no catchment. In summary, the performance of the Edwards is predominantly controlled by minor raveling except at the contact of the Glen Rose and in isolated cases where persistent joints are oriented in an unfavorable direction.

5.7 Catchment Adequacy

The adequacy of a slope's catchment area is determined by whether or not debris falling from the slope face reaches the roadway, and how often. Catchments for the sites observed consisted of many different configurations including flat, vegetated and unvegetated easements, gentle and steep natural ditches, concrete ditches and asphalt paving extending to the toe of the slope. For this project the catchment adequacy was rated from 0 (worst) to 3 (best) according to the frequency of debris reaching the roadway (Table 5.6). The catchment descriptions noted during the field observations along with the assigned catchment adequacy, based on maintenance information, are presented in Tables 5.7 and 5.8. It should be noted that the catchment adequacy is a function of not only the slope and catchment geometries but also on the performance of the slope itself. A completely stable slope with no form of local failure may have a 1-m wide ditch that is completely adequate for the particular slope. Conversely, if the same slope is susceptible to severe raveling, debris could quite possibly enter the roadway.

Table 5.1. Performance Observations of Austin District Sites.

Site Code	Location	Geologic Formtn.[1]	H (m)	L (m)	Type of Failure[2]	Scale	VSR[3]	MR[4]
360-1	Loop 360, N. of RM 2222	Kgr	22.5[b]	300	R,W,DE	local	1	2
360-2	Loop 360 at RM 2244	Ked, Kwa, Kgr	24.3[b]	390	R	local	N/A	0-1
360-3	Loop 360, 1.6 km N. of Wild Basin Road	Kgr	6.6	117	R	local	3.5	3
620-1	RM 620 at Mansfield Dam	Kgr	10.5	279	R, possible DE	local	4	New Cut
620-2	RM 620 So. of Lakeway	Kgr	9[b]	228	R	local	3	3
2244-1	RM 2244 at Crystal Creek Road	Kgr	6.6	111	R	local	3	3
2244-2	RM 2244 at Addie Roy Road	Kgr	5.4	165	R,DE	local	2	3
SWP-1	Southwest Parkway, east of US 71	Kgr	7.5	330	R,DE	local	3	3
SRR-1	Steiner Ranch Road at Quinlan Park Road	Kgr	9	168	R,DE	local	2.5	0
Au-1	RM 2222 between Loop 360 and Mopac	Kgr	>15	>1 km	R,DE	local	2	0
Au-2	RM 2222 at Loop 360 drainage channel	Kgr	7.5	45	R,DE	local	1	0-1
Au-3	Lake Georgetown spillway	Ked	14	1.6 km	R	local	N/A	N/A
Au-4	US 87 north of Mason	Ked	12	110	R,DE	local	N/A	3

Notes: [1] Kgr=Glen Rose Formation, Ked=Edwards Formation, Kwa= Walnut Formation
[2] R=raveling, DE=differential erosion, W=wedge
[3] Visual Stability Rating (Table 5.4)
[4] Maintenance Rating (Table 5.5)
[b] indicates benched cut
N/A = Not Available

Table 5.2. Performance Observations of Dallas and Ft. Worth District Sites.

Site Code	Location	Geologic Formation	H (m)	L (m)	Type of Failure[1]	Scale	MR[2]
D-1	Loop 303 ea. of Loop 12	Austin Chalk, Eagle Ford Shale	4.5	61	R,DE	local	2
D-2	IH 30 at Hampton Road	Austin Chalk	6	120	R	local	3
D-3	IH 30 at Loop 12	Austin Chalk, Eagle Ford Shale	11	150	C,R,DE	local	2
D-4	FM 1382 , Cedar Hill	Austin Chalk	11	60	R	local	
D-5	New Clark Rd. at FM 1382	Austin Chalk	12	73	R,DE	local	3
FW-1	US 377 between Granbury and Cresson	Comanche Peak	5.5	156	B,R	R-local B-global	2
FW-2	SH 16 west of SH 337	Winchell, Wolf Mt.	20	500	R,DE	local	0

Notes: [1] R=raveling, DE=differential erosion, C=circular, B=block failure
[2] Maintenance Rating (Table 5.4)

Table 5.3. Performance Observations of San Antonio District Sites.

Site Code	Location	Geologic Formtn.[1]	H (m)	L (m)	Type of Failure[2]	Scale	VSR[3]	MR[4]
281-1	US 281, S. of Cibolo Creek	Kgr	6	276	R,DE	local	1	2
281-2	US 281 at Belverde Estates	Kgr	7.5	156	R,W	local	2	3
281-3	US 281 just S. of SH 46	Kgr	10.5	375	R,DE	local	2	0-1
281-4	US 281 , 7.9 km S. of Guadalupe River	Kgr	4.5	189	P,R	R-local P-global	2	1
281-5	US 281 just N. of 281-2	Kgr	9	330	P,R	R-local P-global	3	1
1376-1	FM 1376 N. of Boerne	Kgr	13.5	138	R	local	0.5	0-1
1376-2	FM 1376 S. of FM 473	Kgr	9	317	T,R	local	0.5	0
1-10-5	IH-10 near FM 289	Kgr	7.5	137	R,DE	local	1	3
2722-1	FM 2722	Kgr	18.3[b]	108	R, potential P	R-local P-global	4	2
2673-1	FM 2673 at FM 2722	Kgr	7.5	180	R,DE	local	0.5	2
3159-1	FM 3159 N. of SH 46	Ked	6	360	R	local	4	2-3
I-10-1	0.8 km E. of SH 16	Ked/Kgr	22[b]	300	R, DE(Kgr)	local	4	2
I-10-2	2.4 km E. of SH 16	Ked	7.5	216	R	local	3	2
I-10-3	IH 10 at Cypress Creek	Ked/Kgr	21[b]	360	R,(C,DE-Kgr)	local	1	3
I-10-4	IH 10 W of Cypress Cr.	Ked/Kgr	16.5	300	R	local		2
I-10-6	IH 10 , 1.6 km W. of SH 16	Ked	21	105	R	local	4	2
I-10-7	IH 10, 1.6 km W. of FM 783	Ked	5.5	180	none	N/A	4	3
I-10-8	IH 10 just E. of FM 1338	Ked/Kgr	24	308	R,W,DE	local	3	1
I-10-9	IH 10 in Gillespie Co.	Ked	7.5	360	R	local	3	3
41-1	SH 41 at SH 27	Ked	10.5	300	R	local	2	2
187-1	FM 187 N. of Lost Maples	Ked	15	780	R	local	3.5	3
337-1	FM 337 at Mill Creek	Ked/Kgr	18	195	R,T(Ked) DE(Kgr)	R-local T-global	1.5	0
337-2	FM 337, Mill Creek Pass	Ked	7.5	190	R	local	3	1
470-1	FM 470, Tarpley Pass	Ked/Kgr	16.5	293	R, (DE-Kgr)	local	0.5	2
211-1	SH 211N. of FM 471	Ked	10[b]	300	R	local	2	3
211-2	SH 211 N., of Bexar Co. line	Ked	17[b]	550	R	local	2.5	3
211-3	SH 211 S. of SH 16	Ked	30[b]	420	R	local	2.5	2
1283-1	FM 1283 at CR 270	Kgr	15	225	R	local	3	3
1283-2	FM 1283 1.4 km S of PR 37	Ked	10.5	170	R	local	3	2
173-1	FM 173 S of Bandera-Medina Co. line	Ked	15	330	R	local	3.5	3
S-1	Loop 1604 at Bitters Road	Ked	8	>2 km	R	local	3.5	2
S-2	Loop 1604 at Gold Canyon	Ked	5.5	400	R	local	4	3

Notes: [1] Kgr=Glen Rose Formation, Ked=Edwards Formation

[2] R=raveling, W=wedge, DE=differential erosion, T= toppling, P= planar, C=circular

[3] Visual Stability Rating (Table 5.4)

[4] Maintenance Rating (Table 5.5)

[b] indicates benched cut

Table 5.4. Visual Stability Rating Scheme Based on Remaining Percentage of Excavated Face

Visual Stability Rating (VSR)	Percentage of Original Excavated Face Remaining
0	less than 25%
1	25 to 50%
2	50 to 75%
3	75 to 90%
4	greater than 90%

Table 5.5. Maintenance Rating Scheme Based on Maintenance Frequency.

Degree of Local Stability	Maintenance Rating (MR)	Maintenance Frequency
Unstable; frequent maintenance, widespread degradation or localized failures	0	> 4 times per yr
Partially Stable; regular maintenance required	1	2 to 4 times per yr
Stable; some debris, regular but infrequent maintenance	2	1 time per 2yr to 2 times per yr
Completely Stable; little if any degradation, little maintenance	3	< 1 time per 2yr

Table 5.6. Catchment Adequacy Rating Based on Frequency of Debris in Roadway.

Catchment Adequacy	Frequency of Debris Reaching Roadway
0	>4 times per year
1	1 to 4 times per year
2	1 time in 10 years to 1 time per year
3	None to 1 time in 10 years

Table 5.7. Catchment Information for Austin, Dallas and Ft. Worth District Sites.

Site Code	Slope Height (m)	Horizontal Distance from Toe to Pavement (m)	Catchment Description[1]	Catchment Adequacy Rating[2]	W_c/H_s[3]
360-1	22.5[b]	4.5	gentle ditch	2	0.20
360-2	24.3[b]	7.5	gentle ditch	0[*], 3	0.31
360-3	6.6	7.5	flat, grassy easement	3	1.14
620-1	10.5	7.5	gentle ditch	3	0.7
620-2	9[b]	6	flat, grassy easement	3	1.0
2244-1	6.6	3	flat, grassy easement	3	0.45
2244-2	5.4	4.5	gentle, grassy ditch	3	0.82
SWP-1	7.5	3	shallow rip-rap lined ditch	3	0.40
SRR-1	9	1.8	grassy easement slopes toward roadway	0	0.20
Au-1	15	1.8 to 3	varies from gentle to steep ditch	0	0.12-0.20
Au-2	7.5	N/A, slope is in drainage channel	N/A	N/A	N/A
Au-3	14	>15	flat easement	3	>1.10
Au-4	12	1.2	steep, grassy ditch	3	0.1
D-1	4.5	1.8	flat, grassy easement	1[*], 3	0.40
D-2	6	4.5	flat, grassy easement	3	0.75
D-3	11	no information	no information	3	--
D-4	11	4.5	flat, grassy easement	No information	--
D-5	12	4.5	flat, grassy easement	3	0.38
FW-1	5.5	9	gentle, grassy ditch	3	1.63
FW-2	20	3 (prior to re-excavation), 45 (after)	flat easement	0[*], 3	0.15

Notes: [1]Catchment Description: gentle = ditch slope flatter than 4H:1V, steep = ditch slope steeper than 4H:1V

[2] Catchment Adequacy Rating (Table 5.6)

[3] Ratio of catchment width to slope height (or height of lowest bench)

[b] Indicates benched cut

[*] Catchment adequacy prior to corrective maintenance to catchment or slope (e.g., benching, guard rail, re-excavation)

Table 5.8. Catchment Information for San Antonio District Sites.

Site Code	Slope Height (m)	Horizontal Distance from Toe to Pavement (m)	Catchment Description[1]	Catchment Adequacy Rating[2]	W_c/H_s[3]
281-1	6	6	gentle, grassy ditch	3	1.00
281-2	7.5	6	gentle, grassy ditch	3	0.80
281-3	10.5	6	gentle, grassy ditch	3	0.57
281-4	4.5	6.6	gentle ditch	3	1.47
281-5	9	7.5	flat easement	3	0.83
1376-1	13.5	3	flat easement	1	0.22
1376-2	9	0	pavement extends to slope	0	0
I-10-5	7.5	17	flat, grassy easement	3	2.27
2722-1	18.3[b]	9	flat easement	1[*], 3	0.49
2673-1	7.5	3	gentle ditch	1	0.40
3159-1	6	7.5	flat, grassy easement	3	1.25
I-10-1	6.6[b]	7.5	gentle, grassy ditch	3	1.14
I-10-2	7.5	4.8	gentle ditch	3	0.64
I-10-3	5.4[b]	7.5	gentle concrete ditch	3	1.39
I-10-4	16.5	6	gentle, grassy ditch	3	0.36
I-10-6	21	6	flat easement	3	0.29
I-10-7	5.5	7.5	gentle ditch	3	1.36
I-10-8	24	12	gentle ditch	3	0.50
I-10-9	7.5	7.5	flat easement	3	1.00
41-1	10.5	9	flat, grassy easement	3	0.86
187-1	15	0	pavement extends to slope	1	0
337-1	18	0	pavement extends to slope	0	0
337-2	7.5	3	gentle ditch	3	0.40
470-1	16.5	0	pavement extends to slope	1[*], 3	0
211-1	6[b]	3.9	gentle concrete ditch	3	0.65
211-2	6[b]	6	steep ditch	3	1.00
211-3	5.1[b]	7.5	gentle concrete ditch	3	1.47
1283-1	15	7.5	flat easement	3	0.50
1283-2	10.5	6	gentle ditch	3	0
173-1	15	0	pavement extends to slope (sloping toward slope)	3	0.56
S-1	8	4.5	gentle, grassy ditch	3	–
S-2	5.5	no information	no information	3	

Notes: [1]Catchment Description: gentle = ditch slope flatter than 4H:1V, steep = ditch slope steeper than 4H:1V

[2] Catchment Adequacy Rating (Table 5.6)

[3] Ratio of catchment width to slope height (or height of lowest bench)

[b] Indicates benched cut

[*] Catchment adequacy prior to corrective maintenance to catchment or slope (e.g., benching, guard rail, re-excavation)

Fig. 5.1. Example of Planar Failure in Glen Rose (Site 281-4)

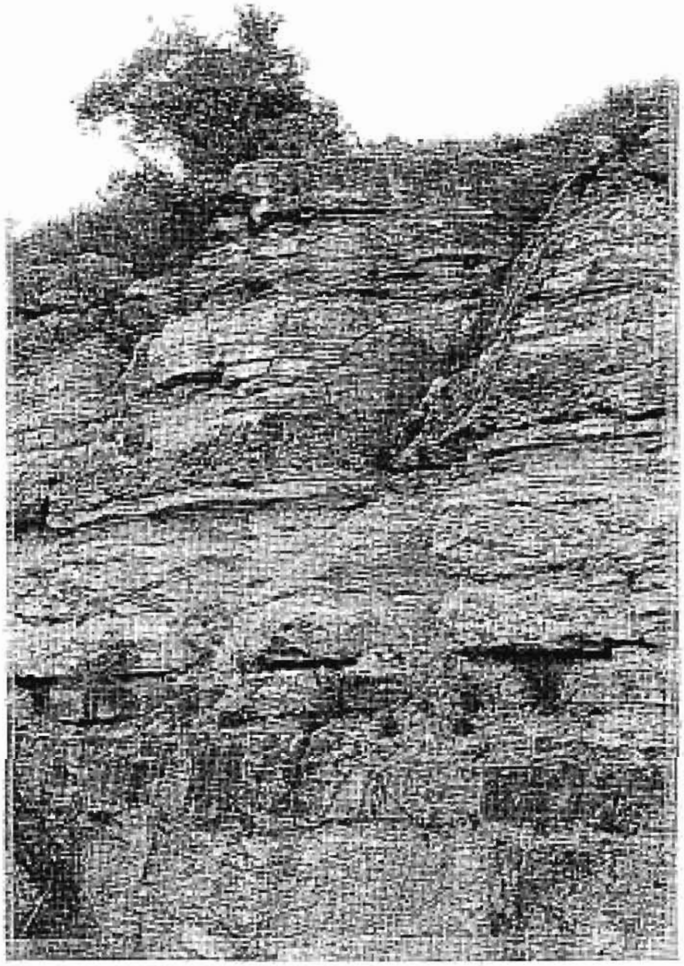


Fig. 5.2. Example of Wedge Failure in Glen Rose (Site 281-2)

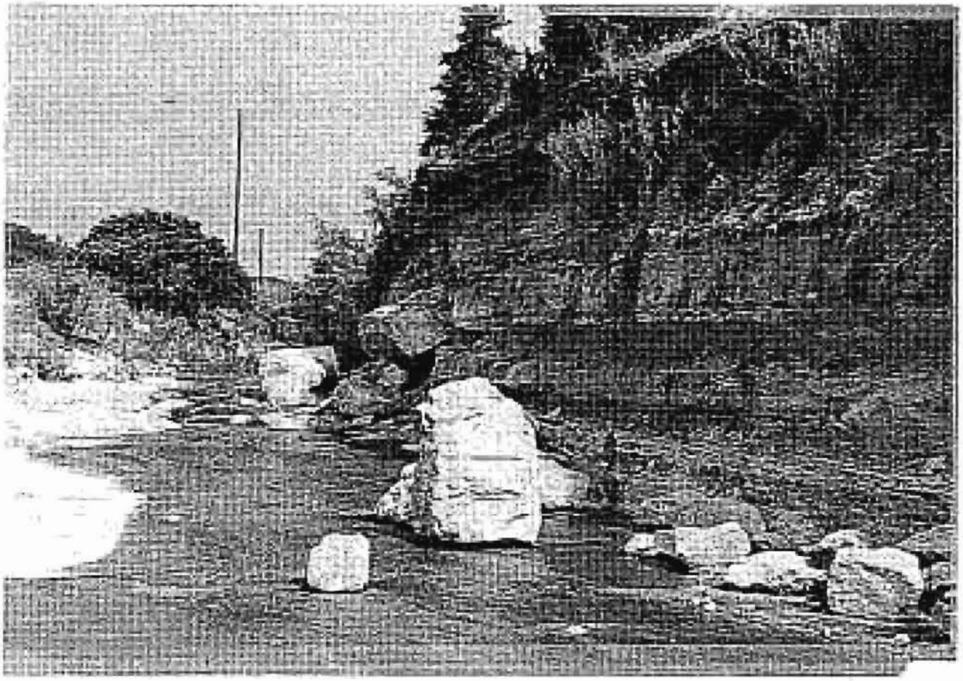


Fig. 5.3. Example of Raveling in Edwards (Site I-10-1)

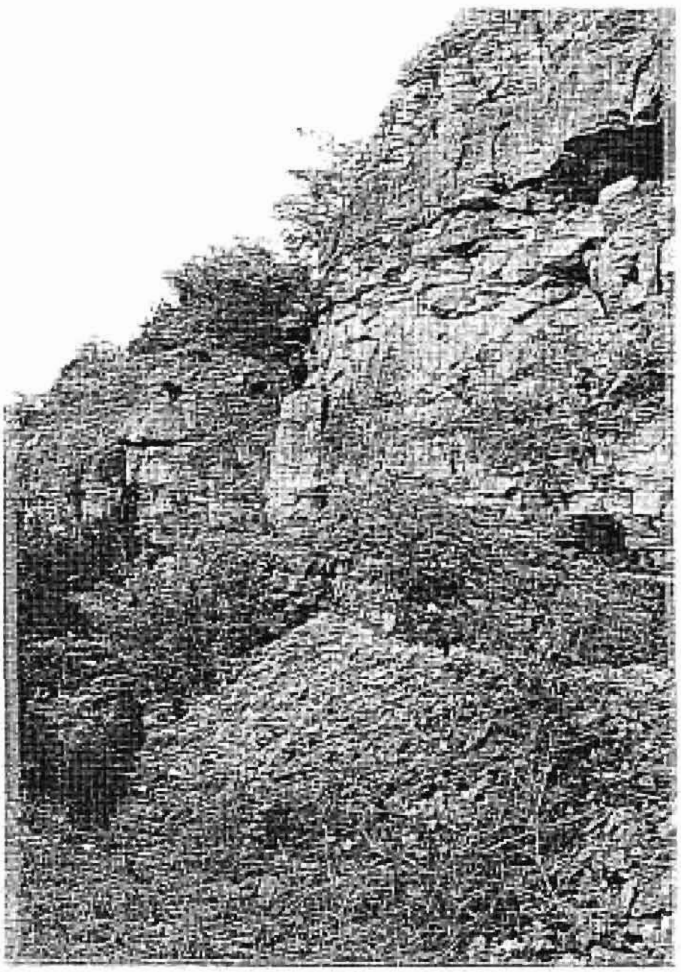


Fig. 5.4. Example of Differential Erosion in Glen Rose (Au-2)

6. PERFORMANCE ANALYSIS

6.1 Introduction

The performance the 53 rock-cut slopes described in Chapter 4 and quantified in Chapter 5 is analyzed in this chapter. Comparisons are made between the observed performance and that predicted by conventional rock mass classification schemes. The weights applied to different parameters in the classification schemes are examined. Additional parameters that may affect performance but are not included in the conventional classification schemes are also identified. Details of the graphical and statistical analyses that support this chapter are presented in Appendix E.

6.2 Factors Affecting Performance

The percentage of total sites within a given geologic formation exhibiting the various modes of failure or degradation is shown on Fig. 6.1. It should be noted that many of the slopes exhibited more than one failure mode. The predominant mode of failure for all three formations is raveling. The two formations containing interbedded softer marl layers (Austin, Glen Rose) contained a significant amount of slopes exhibiting differential erosion which produces cantilevered situations where resistant layers overlying erodible material are undermined and break off due to loss of support. Less than 15 percent of the sites in each formation exhibited the classic kinematic modes of failure such as planar, wedge, and toppling.

The possible factors affecting performance were chosen with the predominant modes of failure as a basis. The potential geologic, geometric, and environmental factors are summarized in Table 6.2. The Rock Quality Designation (RQD) is defined as the percentage of the core run length that is in pieces 100 mm or greater in length. The Degree of Differential Erosion (DDE) is a measure of the erodibility of certain layers. It is defined by the distance back from the face that erodible layers have retreated. The degree of erosion was categorized and assigned a rating according to Table 6.2. The vast majority of slopes were excavated by pre-splitting. Half-cast impressions from the drill holes indicate the original excavated face, making estimation of erosion from the original face fairly simple. In the few cases where half-casts could not be observed, a subjective estimate of the original face was made. DDE is dependent on the relative bed thickness of the rock layers. Thicker layers (both erodible and resistant) generally exhibit greater differential erosion because very thin layers will break or ravel before a large "overhang" is developed. Insufficient data was obtained to fully address this issue of bed thickness. Future data collection in this area may be beneficial.

6.2.1 Geologic Factors

Several of the geologic factors are used in the empirical rock mass classification schemes utilized for characterization of the sites. Bieniawski (1973) developed the Rock Mass Rating (RMR) system which characterizes the rock mass based on six factors including: uniaxial compressive strength, RQD, joint spacing, joint condition, water, and orientation of discontinuities. Weighting factors are assigned for each category and then added to comprise the RMR. Romana (1993) revised the RMR to be more applicable to rock slopes by including factors for joint dip and strike relative to the slope face, and damage due to method of excavation. This revised rating system is called the Slope Mass Rating (SMR) system. Galvan (1995) provides a comprehensive synopsis of these classification systems. The tables used for the classification procedures are presented in Appendix E.

Average RQD values for the sites were estimated visually in the field or calculated from the results of borings for the case-study sites (Appendix C). The RQD values are listed in Tables 6.3 through 6.5 for the Glen Rose and Edwards sites and were also used in the empirical rock mass classification schemes. Local data from a geotechnical consultant (TETCO, 1985-1995) was also gathered for RQD values in the Glen Rose and Edwards Formations in the Austin area. These data, which are shown in Appendix E, are comparable to the RQD values in the borings at the case-study sites and to the field-estimated values. Uniaxial compressive strength (UCS) was used in the rock mass classification schemes and was estimated based on local UCS data (TETCO, 1985-1995). These data are also shown in Appendix E.

Slake durability tests were conducted on core retrieved from one of the case history sites in the Glen Rose (site 620-1) and numerous grab samples taken from both exposed and fresh samples from other sites in the Glen Rose. As described earlier, the Glen Rose contains interbedded marly layers which are more susceptible to erosion than the harder limestone and dolomite layers. By conducting tests on both types of material, it was possible to determine the difference in slake durability between visually erodible and resistant layers. This difference is reported in Tables 6.3 and 6.5 for the sites exhibiting the differential erosion failure mode.

6.2.2 Geometric Factors

Slope height, orientation, angle, and degree of differential erosion were evaluated in the field. The observations, except for slope angle, are shown in Tables 6.3 through 6.5. The slope angles generally ranged from vertical to 15 degrees from vertical.

6.2.3 Environmental Factors

Slope age was determined from construction plans or interviews with maintenance personnel from the respective maintenance sections. The presence of seepage was noted during the field reconnaissance. These two factors are noted in Tables 6.3 through 6.5. Climatic data was gathered from the National Weather Service, however, this information was not used because the weather among the areas studied was very similar in temperature and precipitation. Slope orientation is expressed as clockwise from north. The orientation is determined by turning a circle from 0 degrees (map north) clockwise until the open face of the slope is encountered (Fig. 6.2). For example if a slope strikes N45E and the slope faces the northwest, the orientation would be 45 degrees. If a slope trending in the same direction faced open to the southeast, the orientation would be expressed as 225 degrees. See Figure 6.2. With this definition of orientation, slopes with orientations between 0 and 180 degrees face NW, E, and NE and slopes with orientations between 180 and 360 degrees face SE, W, and SW. The potential effects of orientation are related to sun exposure (e.g., hydro-thermal alteration processes) and wind exposure (e.g., erosion).

6.3 Performance of Formations

6.3.1 Glen Rose

Relationships between slope performance (measured by the Maintenance and Visual Stability Ratings) and the different performance factors (Table 6.3) were investigated. In addition, relationships between MR and VSR were investigated. Results of these analyses are presented in Appendix E and summarized here. As shown in Fig. 6.3, no relationship between RQD and maintenance rating (MR) was observed. The difference in slake durability between non-erodible and erodible layers showed a pronounced relationship with VSR (Fig. 6.4) and DDE. In general, slake durability differences of more than 20 to 30 percentage points indicate large degrees of differential erosion (DDE = 2) and poor performance according to VSR (VSR < 2). The presence of seepage tends to increase the degree of differential erosion (Fig. 6.5). Possible relationships between the rock mass factors (RMR, SMR) and the Maintenance and Visual Stability Ratings were also observed although they are not definitive and there is much scatter. The RMR and SMR include several different factors such as uniaxial compressive strength, RQD, joint spacing/condition, water, etc. and would be expected to show a more conclusive relationship than any of the single variables alone; however, they do not. Finally, the presence of seepage had a significant effect on the Maintenance and Visual Stability Ratings (Figs. 6.6 and 6.7).

6.3.2 Edwards

No relationships were found between the performance factors and the performance measures for the sites in the Edwards Formation. None of the factors or combinations of factors used to assess performance appear to control the actual performance in the field. Minor raveling was the predominant mode of degradation observed. In the field, the raveling appeared to come from layers that possessed closely spaced bed-confined joints that produced small blocks. The presence of these discontinuous joints is suspected to control the performance of the slopes exhibiting raveling. The rock mass classification schemes are not sensitive to the presence of bed-confined discontinuities. Graphs of all factors, including the RMR and SMR classifications, are contained in Appendix E.

6.3.3 Austin Chalk Sites

Since only five sites were observed in the Austin Chalk geologic formation, insufficient data were available for analysis. However, the Austin Chalk has a similar lithologic character to that of the Glen Rose (alternating hard and soft layers) and the sites observed exhibited raveling and four of the five exhibited differential erosion. Based on this limited information, the Austin Chalk sites are expected to behave similarly to rock cut slopes in the Glen Rose Formation.

6.3.4 Comparison Between Formations

The performance factors and the performance measures (MR and VSR) for the Glen Rose and Edwards sites, as well as the sites where the Edwards was exposed on top of the Glen Rose Formation, were compared. With the exception of RQD, all performance *factors* were higher or more favorable for the Edwards Formation. The performance *measures* (MR and VSR) were also higher or more favorable in the Edwards versus the Glen Rose. Table 6.6 summarizes the average values of the pertinent factors and performance measures for the three groups of sites.

6.4 Catchment Analysis

The adequacy of the catchment areas was evaluated using a catchment adequacy rating factor based on the frequency of rockfall reaching the roadway (Table 5.6). The catchment adequacy as a function of catchment (or ditch) width, W_c, in relation to the slope height, H_s is shown on Fig. 6.8. The adequacy generally increases with increasing W_c/H_s. However, there is a fair amount of scatter due to the variance in slope performance (e.g., certain slopes produce more rockfall than others, some do not produce any) and the variability in catchment *shape*. The solid points represent the average W_c/H_s ratio at each adequacy category. The curve does not go through the point at an adequacy rating of 2 because there is only one data point. While there is scatter in the data, a reasonable conclusion would be that a catchment width of at least 0.5H, where H is the slope height, would be necessary to achieve the best catchment adequacy rating of 3 (corresponding to 0 or 1 events of debris reaching the roadway in 10 years).

Previous work in the area of rockfall prediction and control has been done to address the design of catchments. Ritchie (1963) conducted field tests by rolling hard, basaltic rocks down slopes of different geometries and produced design charts for catch ditches with varying widths and depths as a function of slope height and angle. Of more relevance to the slopes in Texas, the Oregon Dept. of Transportation (ODOT) funded research on catchment geometry for slopes with angles of 0.25H:1V (Pierson, et. al., 1994). Rocks were rolled off the top of three different slopes (12 m, 18m, and 24m) all having an angle of 0.25H:1V. Catch ditch configurations varied from flat to 6H:1V and 4H:1V (sloping back toward the toe slope). Impact distance and roll-out distance were tabulated and design charts of ditch width vs. slope height were developed for various degrees of retention. Charts for retention rates varying from 30% to 100% are provided (Pierson et al., 1994); Fig. 6.9 is the design chart for retaining 90% of the rockfall. The 90% retention rate design chart is shown because Pierson concluded that a catchment designed to retain 100 percent of the rockfall is uneconomical and recommended a 90% retention rate for design. He implies that a 90 to 95 percent retention rate is probably most appropriate. For example, consider a an 18-m high slope with a ditch width of 7.2 m and a 6H:1V ditch slope, which corresponds to $W_c/H_s = 0.4$. The catchment would theoretically be sufficient to catch 90% of rockfall (Fig. 6.9). However, if 100% retention was desired, the ditch width would have to be increased to 14.7 m, requiring an additional excavation of 135 cubic meters per meter of slope length. The majority of the catchments observed for this project in Texas were either flat easements or gently sloping ditches (4H:1V or flatter).

A comparison of the design values from Fig. 6.9 with the actual catchment widths was made to assess the applicability of this design method in Texas. The results are tabulated in Table 6.7. The minimum slope height in the design charts is 12 m and unfortunately, only 12 slopes met that criteria. The 4H:1V design curve was used for both "steep ditches" and "gentle ditches." This approach is conservative for steep ditches. With only one exception, slopes with catchment adequacy ratings less than 3 have catchment widths less than the recommended design values. Hence, this proposed design approach seems to be appropriate for Texas rock cuts. Note slopes with catchment adequacy ratings of 3 have ditch widths that are both greater and less than the design width. This result illustrates the influence of slope performance on catchment adequacy.

Smaller ditch widths may be adequate for slopes that do not ravel or display differential erosion. While the initial results of the ODOT design procedures seem to compare well with observed conditions for slopes with rockfall potential, much more data is needed to access the applicability of the ODOT procedures.

6.5 Performance of Nailed Slopes

In the short times that the three case-study slopes with rock nails (Table 4.5) have been in place, they have performed well. There were no signs of distress or degradation in the nailed slopes at the time of the field reconnaissance. It is also of interest to compare the performance of the nailed slopes with unsupported slopes at the same site. At Case-Study site 1 (RM 620 west of Mansfield Dam), the unsupported slope has exhibited minor raveling and differential erosion, although its Visual Stability Rating is 3 (the maximum rating is 4). The unsupported slopes near the nailed bridge abutment at Case-Study site 2 (IH 30 at Hampton Road) have also localized degradation with raveling, differential erosion and circular failures in weathered rock. There is also evidence of erosion around the bridge abutment. At Case-Study site 3 (Loop 1604 at Bitters Road), unsupported slopes have exhibited raveling with a Visual Stability Rating of 3.5 (out of 4) and a Maintenance Rating of 2 (out of 3). In all cases, the successful performance of the nailed slopes versus the unsupported slopes at the same location could be attributed primarily to the facing panels that limit weathering and erosion.

6.6 Conclusions

In the Glen Rose Formation, relationships appear to exist between performance and 1) the presence of seepage, 2) the presence of erodible marl layers adjacent to harder resistant layers in the slope stratigraphy, 3) RQD, and 4) the RMR and SMR rock mass classification ratings. However, the relationships with the latter two factors are not very strong. There appeared to be no relationship between age and performance of the slopes as a whole. This does not mean that a particular slope does not degrade over time because most slopes do. However, when the Visual Stability or Maintenance Ratings are plotted versus the age of the slopes (Appendix E), there does not appear to be a relationship. This result implies that there is significant variability in the stratigraphy and/or other geologic factors such as RQD, joint spacing, joint conditions, water presence, etc. between sites. The predominant failure modes are raveling and raveling/block fall due to differential erosion. A very limited number of sites exhibited classical kinematic type rock slope failures such as toppling, planar, wedge modes. These failures or potential failures can be attributed to faults and associated joint sets in the cases of planar and wedge failures, and these sites are located in areas of the districts where faults are mapped. The one site exhibiting the toppling mode of failure contains very closely spaced (less than 1m) vertical joints oriented nearly parallel to the slope face. The site exhibiting a classical soil-like circular slump failure was located in the San Antonio District (site I-10-3). This particular slope contains several benches and the layers within a mid-slope bench contained softer material that had weathered to a soil-like consistency and was not stable at the original excavated slope (about 20 degrees from vertical).

The performance of the Edwards Formation sites was not predicted by any of the data collected. Like the Glen Rose, the most predominant failure mode is raveling, although the Edwards sites have performed better than the Glen Rose as a whole. One site exhibited wedge failure, and one site had toppling failure. Most of the factors used to evaluate the performance were more favorable for the Edwards sites. The performance characteristics of the Edwards Formation, based on the number of sites observed, are minor raveling, with possible localized differential erosion of solution collapse features (although many of these are well cemented and very stable), and occasional local or global wedge or toppling failures depending on the orientation of joints/faults relative to the slope face. The toppling on site 337-1 in Bandera County extended the full height of the slope. Massive planar type failures were not observed. However, failures of this nature are certainly possible in areas where faults are present, depending on the orientation and dip of the discontinuity relative to the slope face.

Insufficient data were collected on the Austin Chalk and characterization of the formation is not possible with the limited information. However, of the five sites observed, all exhibited raveling and four of the five exhibited differential erosion. Further study of the Austin Chalk is necessary in order to characterize the performance of the formation.

Table 6.1. Summary of Potential Factors Affecting Performance.

Type of Factor	Factor	Source of Information
Geologic	Geologic formation	field reconnaissance, maps
	Average RQD	core drilling, consultant's literature
	Joint spacing and condition	field reconnaissance
	Rock strength	lab tests on core, consultant's literature
	Slake durability	lab tests on core and grab samples
Geometric	Slope orientation	field reconnaissance
	Slope Angle	field reconnaissance
	Slope Height	field reconnaissance
	Degree of Differential Erosion	field reconnaissance
Environmental	Slope Age	interviews, construction documents
	Rainfall, temp. variations, and freeze occurrences	National Weather Service
	Seepage	field reconnaissance

Table 6.2. Degree of Differential Erosion.

Degree of Differential Erosion (DDE)	Magnitude of Erosion From Slope Face
0	less than 0.3 m
1	0.3 to 0.6 m
2	0.6 m or greater

Table 6.3. Performance Analysis for Glen Rose Sites.

Site	H (m)	Age (yr)	Δ Slake[1]	Seepage	Slope Orient.[2]	DDE[3]	Avg. RQD[4]	VSR[5]	MR[6]	Avg. RMR[7]	Avg. SMR[8]
360-1	22.5[b]	10	12%	YES	180°	2	70	1	2	69.5	75
360-3	6.6	18		NO	235°	0	80	3.5	3	66	74.5
620-1	10.5	1	22%	YES	270°	0	84	4	3	75	67.2
620-2	9[b]	7		NO	155°	0	70	3	3	71	71
2244-1	6.6	7	3%	NO	240°	0	67.5	3	3	62	72
2244-2	5.4	7	5%	YES	250°	1	82.5	2	3	71	77.6
SWP-1	7.5	8	8%	NO	180°	0.5	77.5	3	3	71	81
SRR-1	9	6.5		YES	265°	2	62.5	2.5	0	58.5	54.5
AU-1	>15	22.5		NO		1		2	0		
AU-2	7.5	5.5	56%	YES	50°	2	67.5	1	0		
281-1	6	32		YES	165°	2	62.5	1	2	58	58
281-2	7.5	32		NO	0°	0	63	2	3	68	65
281-3	10.5	32	29%	YES	190°	2	70	2	0.5	60	69
281-4	4.5	32	48%	NO	180°	0	65	2	1	65	49
281-5	9	32		NO	200°	0	95	3	1	67	57
1376-1	13.5	40		YES	0°	0	50	0.5	0.5	46	44
1376-2	9	40		NO	355°	0	70	0.5	0	67	50
I-10-5	7.5	25	32%	NO	160°	2	62.5	1	3	67	66
2722-1	10.5[b]	15		NO	168°	0	62.5	4	2	62	12
2673-1	7.5	25		NO	90°	1	62.5	0.5	2	56	56
1283-1	15	19		NO	195°	0	65	3	3	72	73
Mean	*9.2*	*20*				*0.7*	*70*	*2.1*	*1.8*	*65*	*62*
std. dev.	*4.5*	*13*				*0.9*	*10*	*1.1*	*1.2*	*7.0*	*16*

Notes: [1]Difference in Slake Durability between Erodible and Non-Erodible Layers
[2]Slope Orientation (Fig. 6.2)
[3]Degree of Differential Erosion (Table 6.2)
[4]Rock Quality Designation
[5]Visual Stability Rating (Table 5.4)
[6]Maintenance Rating (Table 5.5)
[7]Rock Mass Rating (Bienawski, 1973)
[8]Slope Mass Rating (Romana, 1993)
[b]Indicates benched cut

Table 6.4. Performance Analysis for Edwards Sites.

Site	H (m)	Age (yr)	Seepage	Slope Orient.[1]	DDE[2]	Avg. RQD[3]	VSR[4]	MR[5]	Avg. RMR[6]	Avg. SMR[7]
AU-3	14	22	NO		0	57.5			61	53
AU-4	12	42.5	NO	145°	0	70		3	68	68
3159-1	6	17.5	NO	225°	0	90	4	2.5	76	66
I-10-2	7.5	25	NO	100°	0	80	3	2	66	69
I-10-6	21	25	NO	270°	0	85	4	3	76	77
I-10-7	5.5	25	NO	120°	0	80	4	3	76	84
I-10-9	7.5	25	NO	285°	0	20	3	3	55	65
41-1	10.5	27.5	NO	255°	0	70	2	2	65	63
187-1	15	30	NO	40°	0	92.5	3.5	3	88	98
337-2	7.5	20	NO	90°	0	77.5	3	1	76	75
211-1	6[b]	3	NO	25°	0	30	2	3	62	70
211-2	6[b]	3	NO	235°	0	40.5	2.5	3	65	74
211-3	5.1[b]	3	YES	140°	0	60	2.5	2	73	74
1283-2	10.5	19	NO	0°	0	75	3	2	72	75
173-1	15	30	NO	350°	0	75	3.5	3	74	74
S-1	8	10	NO	222°	0	25	3.5	2	68	68
S-2	5.5	1	NO		0	60	4	3	62	62
Mean	***9.6***	***19***				***64***	***3.2***	***2.5***	***69***	***71***
std. dev.	***4.5***	***12***				***23***	***0.7***	***0.6***	***7.9***	***9.8***

Notes: [1]Slope Orientation (Fig. 6.2)
[2]Degree of Differential Erosion (Table 6.2)
[3]Rock Quality Designation
[4]Visual Stability Rating (Table 5.4)
[5]Maintenance Rating (Table 5.5)
[6]Rock Mass Rating (Bienawski, 1973)
[7]Slope Mass Rating (Romana, 1993)
[b]Indicates benched cut

Table 6.5. Performance Analysis Sites with Edwards Exposed over Glen Rose.

Site	H (m)	Age (yr)	Δ Slake[1]	Seepage	Slope Orient.[2]	DDE[3]	Avg. RQD[4]	VSR[5]	MR[6]	Avg. RMR[7]	Avg. SMR[8]
I-10-1	6.6[b]	25	5%	yes	180°	2	82.5	4	2	77	85
I-10-3	5.4[b]	25	63%	yes	90°	2	37.5	1	2	66	65
I-10-4	16.5	25	22%	no	270°	1	82.5	3	2	80	89
I-10-8	24	25		yes	280°	2	95	3	1	82	67
337-1	18	20		yes	90°	1	80	1.5	0	68	70
470-1	16.5	30	42%	yes	240°	2	46.5	0.5	2	56	56
Mean	*15*	*25*				*1.7*	*71*	*2.2*	*1.5*	*71*	*72*
std. dev.	*7.2*	*3.2*				*0.5*	*23*	*1.4*	*0.8*	*10*	*13*

Notes: [1]Difference in Slake Durability between Erodible and Non-Erodible Layers
[2]Slope Orientation (Fig. 6.2)
[3]Degree of Differential Erosion (Table 6.2)
[4]Rock Quality Designation
[5]Visual Stability Rating (Table 5.4)
[6]Maintenance Rating (Table 5.5)
[7]Rock Mass Rating (Bienawski, 1973)
[8]Slope Mass Rating (Romana, 1993)
[b]Indicates benched cut

Table 6.6. Comparison of Average Performance Factors and Measures.

Formation	Avg. RQD[1]	Avg. DDE[2]	Avg. RMR[3]	Avg. SMR[4]	Avg. VSR[5]	Avg. MR[6]
Glen Rose	69.5	0.7	64.8	61.7	2.1	1.8
Edwards	64.0	0	69.4	71.3	3.2	2.5
Edwards/Glen Rose	70.7	1.7	71.3	71.6	2.2	1.5

Notes: [1]Rock Quality Designation
[2]Degree of Differential Erosion (Table 6.2)
[3]Rock Mass Rating (Bienawski, 1973)
[4]Slope Mass Rating (Romana, 1993)
[5]Visual Stability Rating (Table 5.4)
[6]Maintenance Rating (Table 5.5)

Table 6.7. Comparison of Catchment Widths to Recommended Design Widths.

Site	H[1] (m)	Catchment Shape	Actual W_c (m)	Design Wc^2 (m)	Catchment Adequacy Rating[3]
360-1	22.5[b]	gentle ditch	4.5	6.5	2
360-2	24.3[b]	gentle ditch	7.5	6.8	0
Au-1	15	gentle to steep ditch	1.8	3.7	0
Au-3	14	flat	>15	8	3
Au-4	12	steep ditch	1.2	2.7	3
D-5	12	flat	4.5	4.7	3
FW-2	20	flat	3	14	0
1376-1	13.5	flat	3	7.5	1
I-10-4	16.5	gentle slope	6	4.3	3
I-10-6	21	flat	6	14.5	3
I-10-8	24	gentle slope	12	7	3
1283-1	15	flat	7.5	9	3

Notes: [1]Height of Slope or Lowest Bench
[2]Design Ditch Width (Fig. 6.9)
[3]Catchment Adequacy Rating (Table 5.6)

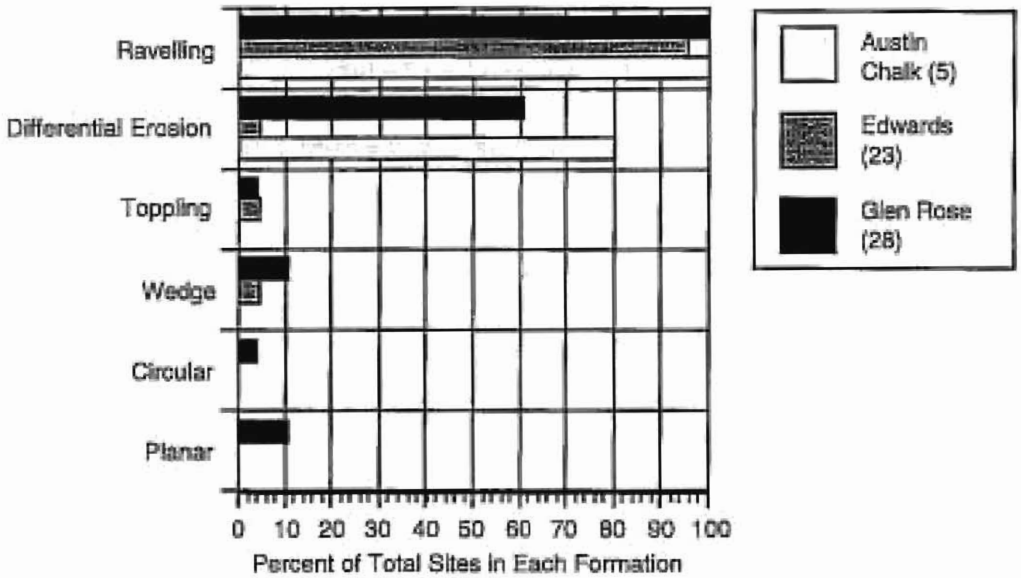


Fig. 6.1. Modes of Failure Observed versus Formation Type.

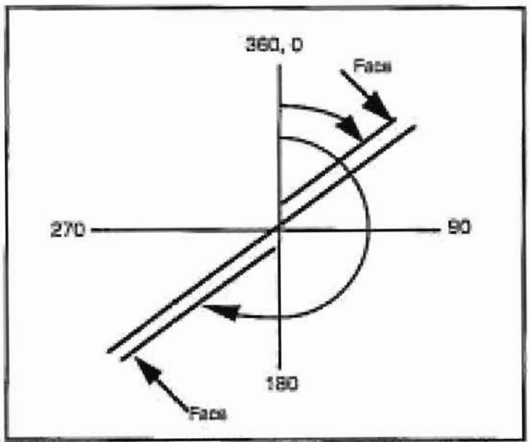


Fig. 6.2. Definition of Slope Orientation.

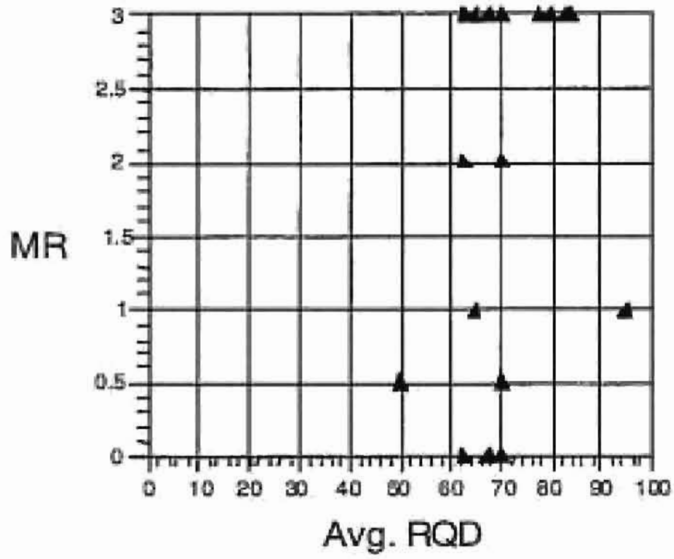


Fig. 6.3. Maintenance Rating versus Rock Quality Designation for Glen Rose Sites.

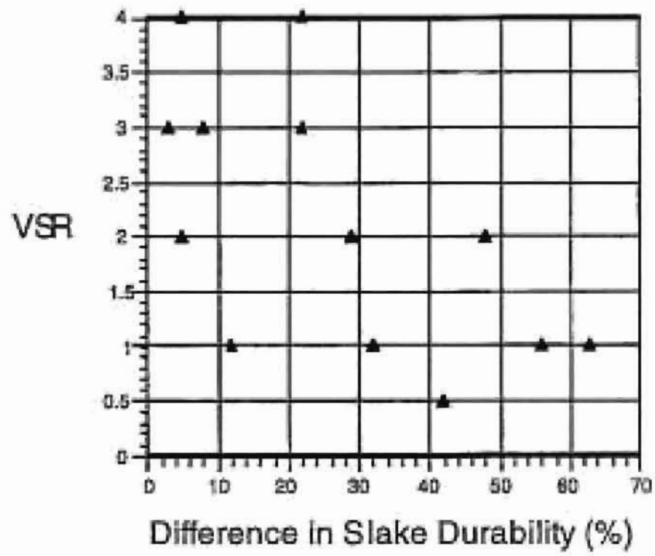


Fig. 6.4. Visual Stability Rating versus Difference in Slake Durability for Glen Rose and Edwards over Glen Rose Sites.

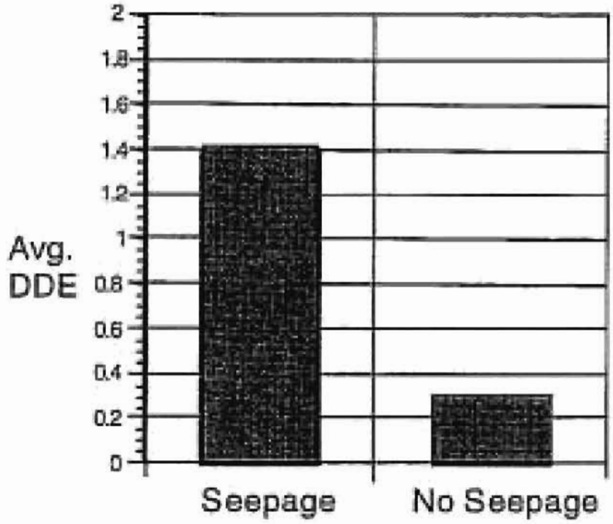


Fig. 6.5. Effect of Seepage on Average Degree of Differential Erosion for Glen Rose Sites.

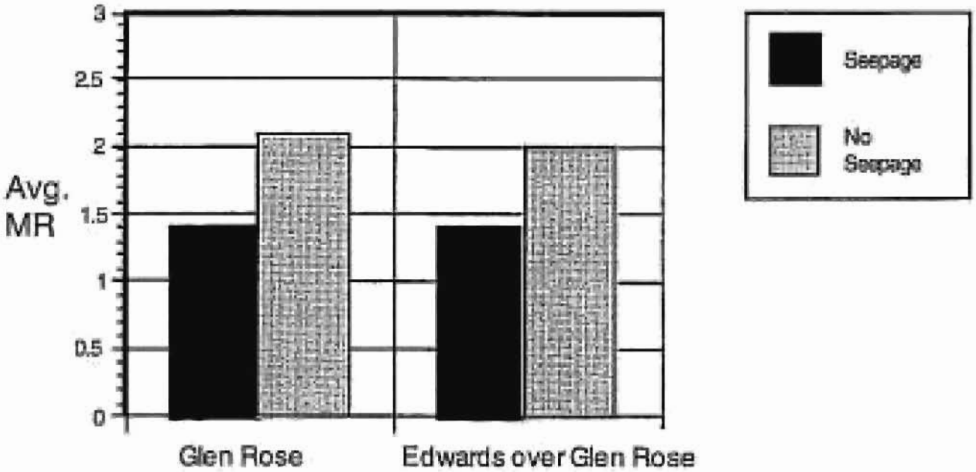


Fig. 6.6. Effect of Seepage on Average Maintenance Rating.

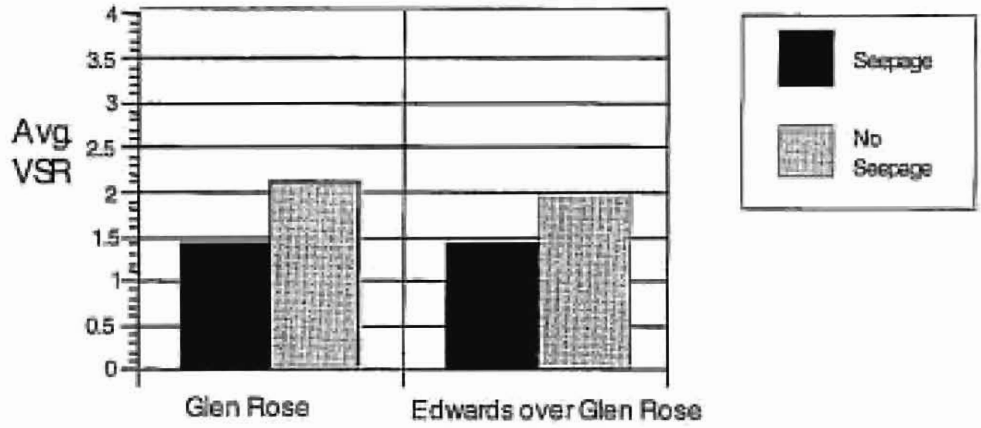


Fig. 6.7. Effect of Seepage on Average Visual Stability Rating.

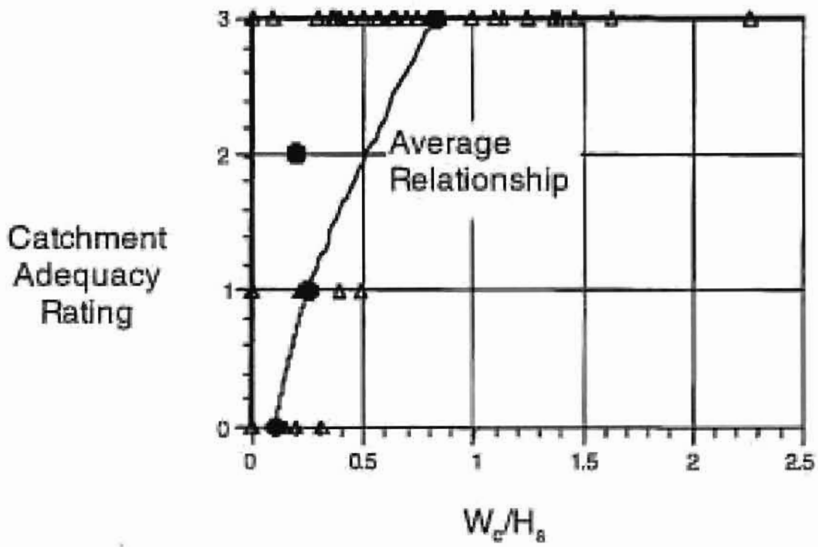


Fig. 6.8. Catchment Adequacy versus Ratio of Ditch Width to Slope Height.

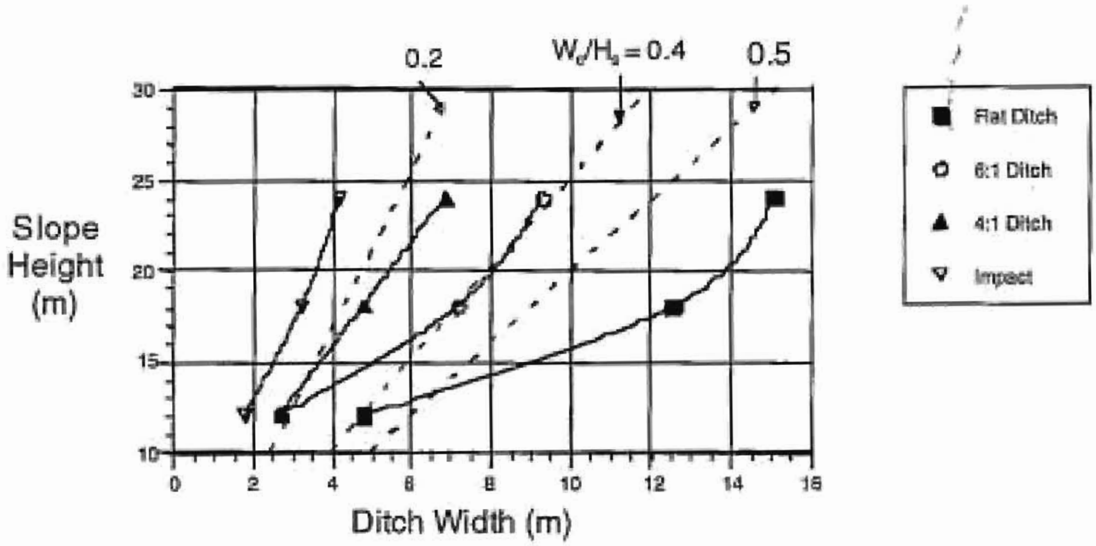


Fig. 6.9. Fallout Design Curves for 90-Percent Retention Rate (Pierson et.al., 1994).

CHAPTER 7. DESIGN OF ROCK NAILS

7.1 Introduction

Rock nails are intended to stabilize rock masses and improve their properties (e.g., stiffness). This chapter presents a design methodology for rock nails based on analysis and experience. Two design approaches are suggested depending on the rock type and condition. The first approach treats the nails as structural members that support and stabilize the rock mass. The second approach treats the nails as low-capacity reinforcing elements that bind (or knit) the rock mass together and prevent localized raveling and degradation. Both approaches have relevance to highway cuts in Texas, although rock nails are not recommended necessarily for every cut.

7.2 Tensile Capacity of Grouted Nails

7.2.1 Introduction

Nails stiffen and strengthen a rock mass by resisting tensile (along the nail), shear (across the nail), and bending (about the nail) stresses. They are considered passive elements in that they will only develop resistance in response to movements within the rock. The relative contributions of tensile, shear and bending resistances depend on the orientation of the nail with respect to movements in the rock, the stiffness of the nail and grout, and the stiffness of the rock and the magnitude of deformations in the rock (Spang and Egger 1990). In typical applications where the cut is near vertical and the bolts are oriented near horizontal, the tensile resistance will be dominant and shear and bending resistances are secondary.

Tensile capacities of grouted nails are typically expressed using the unit ultimate pullout resistance (τ_{ult}). The unit ultimate pullout resistance is an average shear stress acting over the contact surface area between the anchorage and the rock, and is calculated as follows

$$\tau_{ult} = \frac{T}{\pi d L} \tag{7.1}$$

where T is the maximum tensile load, d is the diameter of the anchorage and L is the length of anchorage. Unit ultimate pullout resistance can be estimated from pullout tests by dividing the load at yielding by the surface area of the anchorage (calculated using the nominal diameter of the borehole).

It is important to point out that the unit ultimate pullout resistance should be considered an index value and not an actual resistance encountered along the full length of the nail. The actual distribution of stress along the anchorage zone may be highly non-uniform, particularly when the bond between the grout and the rock remains intact and before relative displacements occur. Figure 7.1 shows results from a theoretical analysis reported by Coates and Yu (1970), as presented by Littlejohn (1993). Coates and Yu determined that most of the load transfer between grout and rock (as shown by the fastest rate of change in the mobilized load) occurs near the front of the anchorage zone. Their study indicates that the stress distribution depends on relative stiffness (in terms of Young's modulus, E) of the grout and the rock. A uniform distribution is not expected unless the grout is very stiff compared with the rock, which is true only for soils and very weak rocks.

7.2.2 Tensile Resistance versus Rock Type

Results of field and laboratory tests reported in the literature were compiled in order to identify typical values of unit ultimate pullout resistance encountered for grouted anchorages in various rock units worldwide. Table 7.1 presents a summary of the results of 43 pullout tests on cement-grouted anchors and 131 load tests on drilled piers (where the tests were carried out to failure). Table 7.2 presents a similar summary for 17 pullout tests on resin-grouted reinforcing elements. The sources and data for these tests are summarized by Whitt (1995).

Information taken only from tests carried out to failure is often biased toward lower strength rocks because, in very strong rocks, testing equipment may not be able to reach the ultimate capacity of the element. A design capacity is more easily achieved using field testing equipment than an ultimate capacity, and proof testing is all that is usually required by contract. Most of the data in Tables 7.1 and 7.2 are from sedimentary rock units, particularly arenaceous (sand-rich) and argillaceous (clay-rich) rocks. Generally higher capacities are found in arenaceous rocks (e.g., sandstones) and limestones. Lower capacities are found for argillaceous rocks (e.g., shales and mudstones) and chalks. Cement and resin grouts display similar values of pullout resistance.

The large values of standard deviation in Tables 7.1 and 7.2 indicate a substantial variability in pullout resistance, even within the same basic rock type. In part, this variability is due to the following factors:

1. Variations in intact rock strengths and rock mass properties;

2. Differences in installation, such as borehole roughness and quality control during grouting;
3. Progressive failure; and
4. The non-uniformities in stress distribution mentioned earlier, which lead to variations in unit ultimate pullout resistance for anchors of different diameters and lengths.

Therefore, these lists are only offered to present an idea of typical τ_{ult} values, and are not a substitute for testing the rocks encountered at a particular project.

7.2.3 Tensile Resistance versus Intact Rock Strength

The strength of the intact rock is a major contribution to the unit ultimate pullout resistance of a grouted element. Many different correlations for estimating τ_{ult} have been developed based on the uniaxial compressive strength (UCS) of the rock, as measured in ASTM D2938. For example, Littlejohn (1993) presents the following correlation between τ_{ult} and UCS for massive rocks (rocks with widely spaced discontinuities)

$$\tau_{ult} = 0.1\text{UCS} \tag{7.2}$$

This equation tends to underpredict τ_{ult} for weaker rocks, particularly weathered clastic sedimentary rocks. The ratio of τ_{ult} to UCS can be as large as 0.3 to 0.4 for weak rocks (Littlejohn 1993). Horvath et al. (1980) report another correlation between τ_{ult} and UCS that takes the concrete strength into account

$$\tau_{ult} = b \cdot f'_w{}^{\frac{1}{2}} \tag{7.3}$$

where f'_w is the controlling uniaxial compressive strength (the lower of the concrete and rock strengths) and b is an empirical factor that varies from 0.2 to 0.25 if τ_{ult} and f'_w are in MPa.

In order to evaluate the applicability of different correlations between τ_{ult} and UCS, the τ_{ult} test data in Table 7.1 are plotted versus UCS on Fig. 7.2. These plots include only test data in which rock strength information was also available. In cases where several tests were performed at one site in the same rock unit, vertical bars on Fig. 7.2 show the mean pullout resistance +/- one standard deviation. Horizontal bars show the range in UCS values for each site.

The ultimate pullout resistance tends to increase with increasing rock strength, although there is substantial scatter in the data. The correlation proposed by Littlejohn (1993), Equation 7.2, provides a lower bound on pullout resistance for UCS values less than about 10 MPa (Fig. 7.2). However, this correlation is less conservative for higher strength rocks where the compressive strength of the grout (f'_c) becomes the controlling factor. The Horvath et al. (1980) correlation in Equation 7.3, which accounts for f'_c, provides a more conservative fit of the data than Equation 7.2 for higher strength rocks (Fig. 7.2b). A similar analysis was not done for resin grouted anchorages because UCS values were only available for a few tests.

7.2.4 Estimated Tensile Capacities for Rock Nails in Texas

The measured UCS values from the samples obtained during this project are presented in Appendix D and summarized in Table 7.3. Based on these values as well as experience with rock bolting for underground openings and tunnels in these formations, a typical τ_{ult} value for each formation studied in this project is provided for use in design as well as a probable range of τ_{ult} values.

7.3 Rock Nail Design Approaches

7.3.1 Introduction

The design of rock nails depends on their intended function. There are two potential modes of failure in Texas slopes that can be controlled and prevented using rock nails: (1) global planar and wedge failures and (2) localized raveling and degradation. A design approach for each of these functions is described in the following sections.

7.3.2 Design for Global Planar and Wedge Failures

Large-scale planar and wedge failures were not common in the 53 slopes that were studied. Global failures were observed in three of the rock cuts that were studied (i.e., Sites 281-4, 281-5 and 2722-1), and all of these failures were in the Glen Rose Formation. However, global failures are possible in cuts where there is a continuous, steeply dipping joint (typically greater than 30° dip) that is oriented near parallel to the cut face and daylights into the cut face (Fig. 7.3). Further, the consequences of a global failure can be severe. Therefore, although global failures are not likely in Texas road cuts, it is of interest to develop a design approach for those instances where they are possible.

7.3.2.1 Total Nail Load

Rock nails provide a lateral force to support an unstable wedge, as shown on Fig. 7.3. The required nail loads can be estimated from force equilibrium, as shown on Fig. 7.4 where the variables are defined as follows:

- P = total nail load (per unit width) required;
- W = weight of wedge (per unit width);
- N = normal force acting on joint (per unit width);
- q = contact pressure due to external loads;
- u = water pressure acting on joint;
- γ = unit weight of rock;
- H = slope height;
- α = dip of joint (measured from horizontal);
- β = orientation of total nail load (measured from horizontal);
- N_q = non-dimensional factor representing external loads, where $q = N_q\gamma H$; and
- N_w = non-dimensional factor representing water pressure, where $u = N_w\gamma H$

For this condition, the required total nail load, P, is obtained from the following expression

$$P = \left\{ \frac{(0.5 + N_q)\tan(90^\circ - \alpha) + 0.5N_w\left[\dfrac{F\ \tan(\alpha_{joint}) - 1}{\tan(\alpha)}\right]}{\cos(\beta)F - \sin(\beta)} \right\} \gamma H^2 \tag{7.4}$$

where

$$F = \frac{\cos(\alpha) + \tan(\phi_{joint})\sin(\alpha)}{\sin(\alpha) - \tan(\phi_{joint})\cos(\alpha)} \tag{7.5}$$

The design implications of this equation are discussed in the following paragraphs.

Dip and Strength of Joint: The total nail load per unit width, normalized by γH^2, is shown on Fig. 7.5 as a function of the joint dip, α, and joint strength, ϕ_{joint}. The required nail load is zero for $\alpha < \phi_{joint}$, and the maximum nail load occurs at a joint dip of $\alpha = 45° + \phi_{joint}/2$. Typical joints observed in the studied road cuts were reasonably rough with little to no infilling, and are expected to have ϕ_{joint} values between 30° and 40°. Most of the discontinuitites were oriented horizontally as bedding planes, which explains why global, planar failures are not very common in these formations. However, there were also joints observed that dipped at between 50° and 70° to the horizontal. These joints, which were associated with fault zones, are especially prominent in the Glen Rose Formation and the Austin Chalk; although they are also present to a lesser extent in the Edwards Formation as well. In general, these steeply dipping joints were not spaced closely enough to cause problems (i.e., they did not daylight in the 10 to 20 m high rock cuts that are typical in Texas), or they were not oriented parallel to the cut face so that the effective dip into the cut was fairly shallow. Also, it is important to point out that Equation 7.4 (and the associated design chart on Fig. 7.5) are only appropriate for planar type failures. If the unstable wedge is bounded by two discontinuities (i.e., a three dimensional sliding surface), then the required nail load obtained from Equation 7.4 will be conservative. References such as Hoek and Bray (1977) provide design charts for three-dimensional sliding surfaces.

External Loads: The effect of external loads is to increase the required nail load, as shown on Fig. 7.6. For traffic loads, a surcharge of approximately 0.6 m of soil is typically assumed for design in accordance with AASHTO Standard Specifications for Highway Bridges (1991). For a typical road cut between 5 and 25 m in height, traffic loads correspond to N_q values ranging from 0.02 to 0.1; therefore, external loads due to traffic are not expected to increase the total required nail load by more than 20 percent (Fig. 7.5). If a bridge abutment were founded at the crest of a rock cut (i.e., not founded on drilled piers that transmit the structural loads down through the rock), then N_q values could be as large as 0.5 and the total required nail load would be doubled. However, this type of a design is rarely implemented in Texas.

Water Pressure: Water pressure along the discountinuity also increases the required nail load, as shown on Fig. 7.7. Water pressure has two effects on the required nail load: it adds a horizontal compact of driving force to the wedge and it reduces the shear resistance along the discontinuity by reducing the normal load. A worst-case condition for water pressure would be that the water table rises to the crest of the slope (i.e., a hydrostatic water pressure of γ_w times the depth below the slope crest). This condition corresponds to an N_w value of approximately 0.5, and a required nail force that is increased by more than a factor of 2 (Fig. 7.7). Also, since the water pressure reduces the normal load on the discontinuity, the discontinuity strength (ϕ_{joint}) becomes less important and the required nail load becomes less dependent on ϕ_{joint} (Fig. 7.7). Therefore, water pressure can lead to large nail loads and the provision of adequate drainage within the slope is an important design consideration.

Nail Orientation: The nail orientations are typically not horizontal due to construction considerations; they are typically oriented at 10° to 15° to the horizontal. The effect of nail orientation on the required nail load is shown on Fig. 7.8. Since the horizontal component of the required stabilizing force is most important due to kinematical constraints (i.e., the wedge movement is horizontal, as shown on Fig. 7.3), the required nail load increases as the dip of the nails increases. Although the most effective nail orientation is horizontal, the difference between horizontal and orientations as large as 20° is not substantial (Fig. 7.8). Also, it is important to note that the nails have been assumed to provide resistance only through tension (i.e., bending and shear resistances are neglected). These other components of nail resistance may become more important as the nail orientation becomes oriented near perpendicular to the joint, and the increase in required nail load with increasing inclination may actually be less than that shown on Fig. 7.8. Therefore, the ease of construction associated with slightly dipping nails probably outweighs any benefit associated with horizontally oriented nails.

Comparison with Apparent Earth Pressure Approach: A common design approach in Texas slopes containing nails (both soil and rock slopes), is to use the apparent earth pressure envelopes developed by Terzaghi and Peck (e.g., Peck, 1969) for braced excavations in stiff clays. The typical envelope being used currently is shown on Fig. 7.9. The equivalent, total nail load associated with this envelope is obtained as follows

$$P = \frac{1}{2}(H + 0.6H)(0.4\gamma H) = 0.32\gamma H^2 \tag{7.6}$$

This total load is shown on Fig. 7.5 together with the curves obtained from Equation 7.4. For typical conditions (i.e., ϕ_{equiv}= 30°, α = 60°, β = 0°, N_q = 0 and N_w = 0), the total nail load estimated from the apparent earth pressure diagram is very conservative with a calculated nail load from apparent earth pressures that is about twice that obtained from Equation 7.4 (Fig. 7.5).

7.3.2.2 Distribution of Nail Loads

The force equilibrium approach described in the previous section provides an estimate for the total nail load required, but does not indicate the loads required in individual nails. In fact, there is an unlimited number of nail load combinations that would satisfy the total nail load requirement. However, there are other considerations in how the total load is distributed to individual nails:

- more lightly loaded nails will generally provide a more redundant system than fewer heavily loaded nails;
- uniformly distributed nail loads will generally be more effective at minimizing deformations during excavation; and
- nails near the top of the cut may improve both local (i.e., smaller wedges) and global stability.

Numerical analyses were performed to investigate how the rock stiffness and construction sequence affected the distribution of nail loads in a rock cut with a planar feature (Fig. 7.3). The Universal Discrete Element Code, UDEC (Itasca 1993), was used to model a rock cut with nails. The studied rock cut was 10 m in height with a planar feature dipping at 60° and daylighting at the toe of the cut. The strength of the discontinuity was assumed to be $\phi_{joint} = 30°$. Six rows of nails were included, and the nails were modeled as tension members with no shear and bending stiffness.

For rock stiffnesses representative of the rocks in the studied slopes (i.e., between 1,000 and 5,000 MPa based on the laboratory testing results in Appendix D), the mobilized nail loads were uniform regardless of the construction sequence. Therefore, it is reasonable to assume that the total nail loads is divided uniformly among the individual nails for typical rock cut designs. For stiffnesses below 50 MPa, which is more typical of a soil, the nails near the middle of the slope mobilized larger loads than those near the top and bottom (similar to the assumed distribution shape shown on Fig. 7.9). Also, for soil-like materials, the top-down construction sequence affected the distribution and magnitude of nail loads.

7.3.2.3 Facing Design

For the planar failure mode, the wall facing is theoretically not necessary. The only requirement is that the nails be secured at the wall face so that they can transfer their full load to the unstable wedge. For fully grouted nails, this consideration is only relevant for the nails near the toe where the nail length within the wedge is short (Fig. 7.3). Even then, most typical element head connections (as described in Chapter 3) will be sufficient to transfer the nail load to the rock wedge.

However, the facing plays an integral role in minimizing local raveling and degradation. Since these failure modes are by far the most common failure modes in the studied slopes and were present even in the slopes exhibiting global failures, some nominal facing support should be provided in all nailed slopes. This facing will serve two functions: it will provide confinement at the wall face to prevent local raveling and it will protect the fresh rock from weathering and erosion.

The facing could range from wire mesh to cast-in-place concrete panels. The pressure on the facing should be minimal because most of the local raveling is related to degradation of the slope; if the degradation is prevented, then the raveling will not occur. Therefore, a 100-mm thick, wire mesh or fiber reinfoced shotcrete facing should be sufficient in most instances. In critical areas, a conservative design approach is to assume that the facing must support an unstable wedge of rock that is defined in size by the nail spacing. These facing loads can then be estimated using the design chart on Fig. 7.5, where the wedge height H is the vertical distance between nail rows.

Drainage is an important consideration in the facing design. If adequate drainage is not provided, water pressure will build up behind the wall and increase the facing loads. Further, water pressure may build up within the slope along discontinuities and increase the required nail loads. Therefore, a drainage material should be placed between the facing and the rock slope and drainage outlets should be included in the facing. In addition, the drain outlets should be periodically monitored for flow during rainy periods to confirm that they remain open over the life of the wall.

7.3.2.4 Design Example

In order to demonstrate the proposed rock-nail design approach for global stability, consider a 10-m high rock cut in a faulted zone of the Glen Rose. Based on field reconnaissance and local experience, the potential exists that a steeply dipping joint may daylight into the excavation. The discontinuity will be assumed conservatively to have a ϕ_{joint} of 30° and dip into the face at 60°. The rock unit weight is assumed to be 23 kN/m^3. A road will be located near the slope crest; a surcharge pressure 10 kPa will be used to represent this external load. Therefore, N_q is equal to 10 kPa/(23 kN/m^3 x 10 m) = 0.043. The nails will be oriented at 15° to the horizontal. Two design cases will be analyzed: N_w equal to 0 (no water pressure) and N_w equal to 0.5 (a worst-case water pressure condition).

Nail Spacing: The total required nail loads are determined from Equation 7.4:

$P = 0.222(23\ kN/m^3)(10\ m)^2 = 511\ kN/m$ for $N_w = 0.0$; and

$P = 0.426(23\ kN/m^3)(10\ m)^2 = 980\ kN/m$ for $N_w = 0.5$.

If reinforcing bars with a diameter of 25 mm ($A_{steel} = 491\ mm^2$) with $f_y = 420$ MPa are used in the rock nails, then the maximum load per nail is 206 kN. For a typical safety factor against steel yielding of 1.5, the allowable load per nail is 137 kN. If it is assumed that the nails are spaced uniformly horizontally and vertically at a distance of s, then the required nail spacings for the two design cases are calculated as follows:

$$s = \sqrt{\frac{(10\ m)(137\ kN\ per\ nail)}{511\ kN/m}} = 1.6\ m \text{ for } N_w = 0.0\text{; and}$$

$$s = \sqrt{\frac{(10\ m)(137\ kN\ per\ nail)}{980\ kN/m}} = 1.2\ m \text{ for } N_w = 0.5.$$

If water pressures are not anticipated in the slope, then the 1.6 m spacing would be sufficient. If water pressures are possible, then the costs of installing a drainage system within the slope versus installing nails spaced at 0.9 m should be compared to determine the optimal design.

Nail Length: The nail lengths are determined from their estimated tensile capacity. Each nail is required to develop a load of 137 kN. From Table 7.3, a unit ultimate pullout resistance of 1.0 MPa is assumed for the Glen Rose Formation. A safety factor of 2.0 against pullout is typically used in soil. Since there are no measured pullout resistances for these types of nails in the Glen Rose Formation at present, a larger safety factor of 3.0 is recommended. This safety factor could be reduced with pullout measurements, especially if they are performed at the particular project site. If a safety factor for pullout of 3.0 is used, then the unit allowable pullout resistance is 333 kPa. *For a grouted annulus of 75 mm, the required anchorage length is obtained as follows:*

$$L_a = \frac{137\ kN}{\pi(0.075\ m)333\ kPa} = 1.7\ m$$

where L_a is the required anchorage length. Therefore, the nails should be anchored at least 1.7 m behind the discontinuity.

Facing Pressure: If adequate drainage is provided within the slope and behind the facing, then the facing pressure can be conservatively estimated from an unstable rock wedge that is bounded by the nails at the wall face (i.e., it is 1.6 m high by 1.6 m wide at the wall face). If it is assumed that the wedge is associated with the joint set that is dipping at 60°, then the design pressure is obtained from Equation 7.4 as follows:

$$w = 0.222(23\ \text{kN/m}^3)(1.6\ \text{m})^2/(1.6\ \text{m}) = 8.2\ \text{kPa}$$

where w is the design facing pressure. This pressure could easily be accomodated by a 100-mm thick layer of shotcrete reinforced with wire mesh or fibers.

7.3.3 Design for Localized Raveling and Degradation

Localized raveling and degradation was by far the most common mode of failure observed in the studied rock cuts. These localized features are typically controlled by bedding planes that are spaced 0.5 to 1.5 m apart and near vertical joints (or tension cracks) that are spaced as close as 0.3 m apart back into the cut face. Rock nails can help support these localized features and stabilize raveling. The nails create a reinforced mass of rock at the face of the cut that acts essentially as a gravity retaining wall.

The following design is recommended for using rock nails to stabilize localized instabilities at the rock cut face: 25-mm diameter steel bolts ($f_y = 420$ MPa) grouted in 75-mm diameter holes, spaced at approximately 1.5 m horizontally and vertically, with a length of 3 m. This design is intended only for the Cretaceous-age sedimentary rocks in central Texas and for rock cuts that are 5 to 30 m in height.

The recommended design is based on the following rationale. First, empirical design procedures for using rock bolts to support cavern walls in underground construction indicate that the bolt length should be about 0.2 to 0.3 times the wall height and spaced at about 0.5 times the bolt length. Second, a simplistic and conservative analysis that treats the reinforced rock as a gravity retaining wall indicates that the wall width needs to be about 3.0 m to prevent overturning when external loads act at the wall crest. Third, the nails need to be spaced at about the same spacing as the bedding features that control the localized raveling. Fourth, an analysis of local instabilities (using Equation 7.4) with a wedge height of 1.5 m (the bedding thickness) indicates that the nail force from a 3.0 m long nail will be sufficient to stabilize the wedge. Finally, a similar design approach was used sucessfully by Hall et al. (1994) to stabilize vertical cuts in the Edwards and Glen Rose Formations at an amusement park near San Antonio.

In cases where a large external load (e.g., a bridge abutment foundation) is to be applied near the slope crest, additional nails that are 6 to 9 m in length (or at least 3 times the foundation width) and spaced at about 3 m should be installed at the crest to prevent a local failure just below the foundation. These nails should be oriented at about 60° to the horizontal to intersect both near vertical joints and near horizontal bedding plane features. Fig. 7.10 shows a schematic of this proposed design approach.

It is important to recognize that nails are not necessarily the best approach to stabilize localized raveling and degradation. In fact, nails will not be sufficient to prevent localized failures alone because the rock around the bolts will be susceptible to weathering and erosion. Therefore, some form of confinement at the wall face, such as shotcrete or wire mesh, should be used in addition to the nails. In cases where the rock mass is not heavily jointed, it should be possible to rely solely on face confinement with no nails (or nails that only serve to support the facing material) to create a stable rock cut that can support external loads. Nails could also be used only in areas of the rock face that are jointed and potentially unstable (i.e., spot bolting).

7.4 Corrosion Protection

Corrosion protection is an important design consideration for rock nails in roadway cuts. The nails will typically be used in critical, permanent structures (e.g., bridge abutments), and some of the rock formations (specifcally the Glen Rose) are aggressive concerning corrosion. When the nails are used for global stability, fully encapsulated nails should be used in accordance with FHWA guidelines for nail corrosion protection on U.S. Federal-aid Highway projects (FHWA, 1993). The nail should be grouted inside a corrugated plastic sheath using a neat cement grout. The minimum grout cover between the tube and the borehole wall should be 12 mm. When the nails are used for local stability, full encapsulation is not necessary. In these applications, a minimum grout cover of 37 mm should surround the nails and centralizers should be used to ensure grout cover along the entire nail length.

7.5 Summary

In summary, rock nails can be used to improve both global and local stability. In road cuts with continuous, steeply dipping discontinuities that are spaced closely enough to daylight at the cut face, nails should be anchored across the discontinuity. A design equation and design charts are provided to estimate the required nail loads. Conventional tiebacks could also be used in place of rock nails to stabilize these slopes effectively, and a cost comparison between the two should be conducted to determine the optimal design. Nominal facing support should be provided in either case to prevent localized raveling and degradation. While global planar failures are possible in Texas road cuts, they are not common.

The most common failure mode in Texas road cuts is localized raveling and degradation. If the rock mass is heavily jointed and fractured, closely spaced, lightly loaded rock nails can be used to provide support to local instabilities. Rock nails are specifically recommended in these rock conditions when a large external load (e.g., a bridge abutment foundation) will be applied near the slope crest. However, in many instances, rock nails are not necessary and confinement at the face (e.g., wire mesh or shotcrete) will serve the same purpose more effectively and less expensively. Altnernative control measures for local instabilities are described in the next chapter.

Table 7.1. Unit Ultimate Pullout Resistance for Different Rock Types (Cement Grouted Anchorages).

Rock Type	Number of Tests	Unit Ultimate Pullout Resistance, τ_{ult} (MPa)		
		Range	Mean	Standard Deviation
Igneous	7	0.12-6.37	2.13	2.37
Metamorphic	3	1.60-5.57	2.99	2.23
Sedimentary				
Arenaceous	83	0.12-9.55	2.05	1.67
Argillaceous	57	0.05-2.50	0.56	0.46
Marl	13	0.10-1.03	0.38	0.31
Mudstone	15	0.12-1.05	0.57	0.26
Shale	24	0.05-2.50	0.63	0.61
Calcareous	18	0.09-4.80	1.27	1.45
Limestone	10	0.09-4.80	1.91	1.69
Chalk	7	0.14-1.07	0.39	0.35

Table 7.2. Unit Ultimate Pullout Resistance for Different Rock Types (Resin Grouted Anchorages).

Rock Type	Number of Tests	Unit Ultimate Pullout Resistance, τ_{ult} (MPa)		
		Range	Mean	Standard Deviation
Igneous	6	1.22-2.29	1.73	0.45
Metamorphic	0			
Sedimentary	11			
Arenaceous	0			
Argillaceous	3			
Shale	3	0.75-3.38	2.29	1.38
Calcareous	8	0.72-3.32	2.27	0.73
Limestone	7	0.72-3.32	2.27	0.79

Table 7.3. Recommended Unit Ultimate Pullout Resistances for Texas Formations.

Rock Formation	Measured UCS (MPa)			Recommended τ_{ult} (MPa)	
	Mean	Range	Standard Deviation	Typical	Range
Glen Rose	12	5 - 30	7	1.0	0.5 - 2.0
Edwards	29	14 - 56	16	2.0	1.0 - 4.0
Austin Chalk	9	2 - 18	5	1.0	0.5 - 1.5

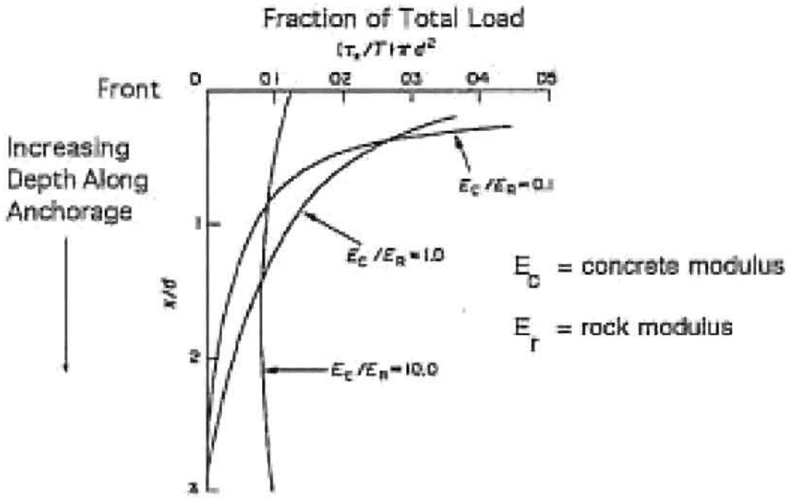
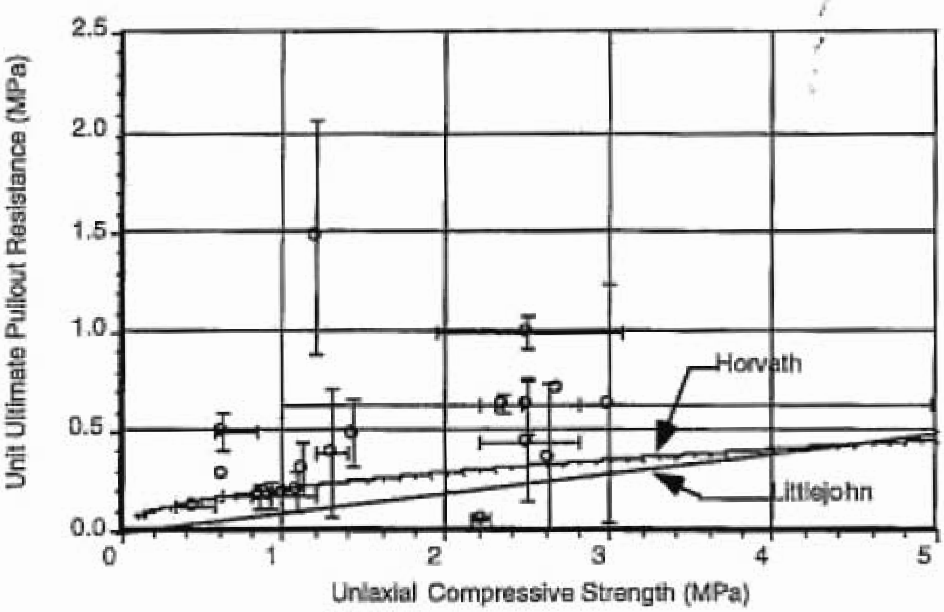
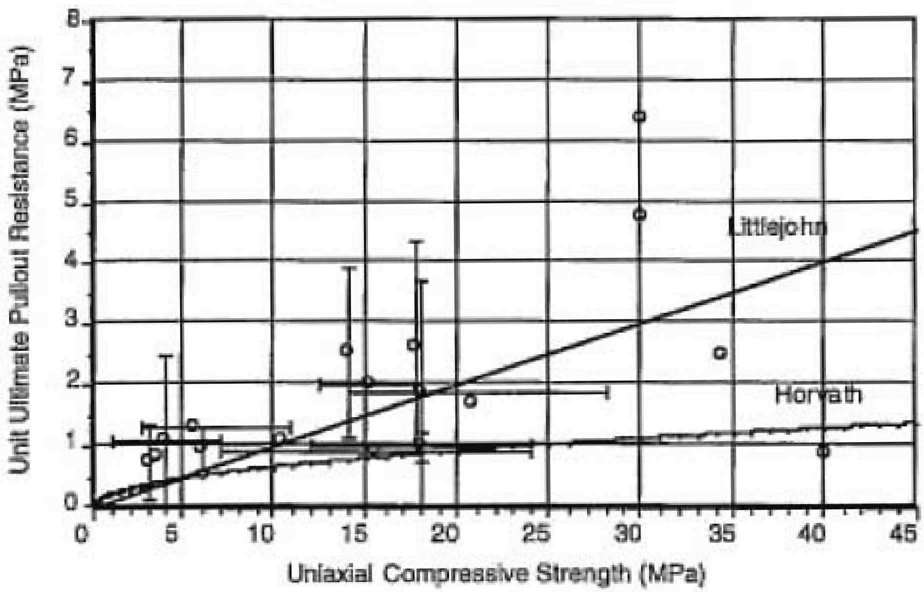


Fig. 7.1. Distribution of Pullout Resistance along a Grouted Reinforcing Element (after Littlejohn, 1993).



a. Cement grouted elements, average UCS < 3.0 MPa.



b. Cement grouted elements, average UCS > 3.0 MPa.

Fig. 7.2. Unit Ultimate Pullout Resistance vs. UCS.

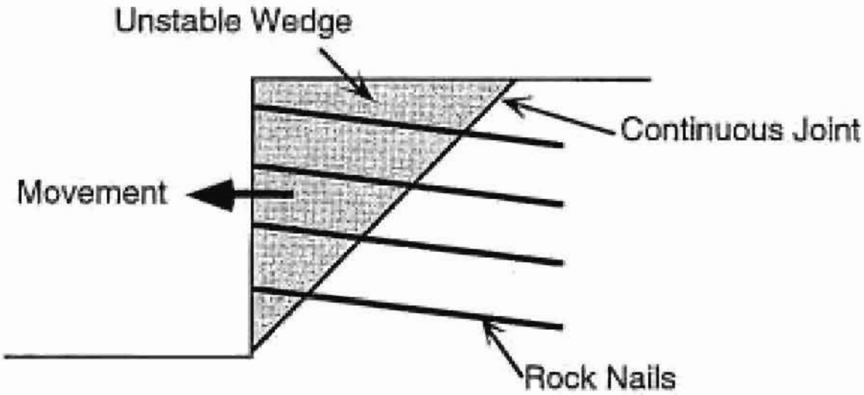


Fig. 7.3. Rock Nails Stabilizing a Global Failure.

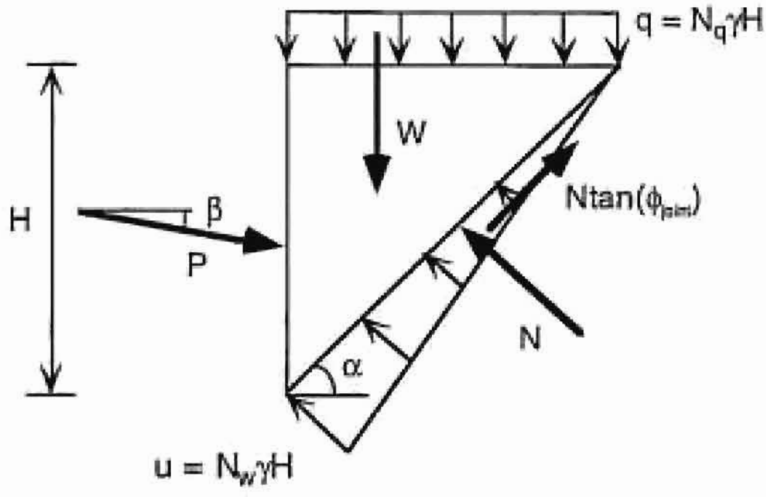


Fig. 7.4. Equilibrium of Unstable Wedge for Nail Design.

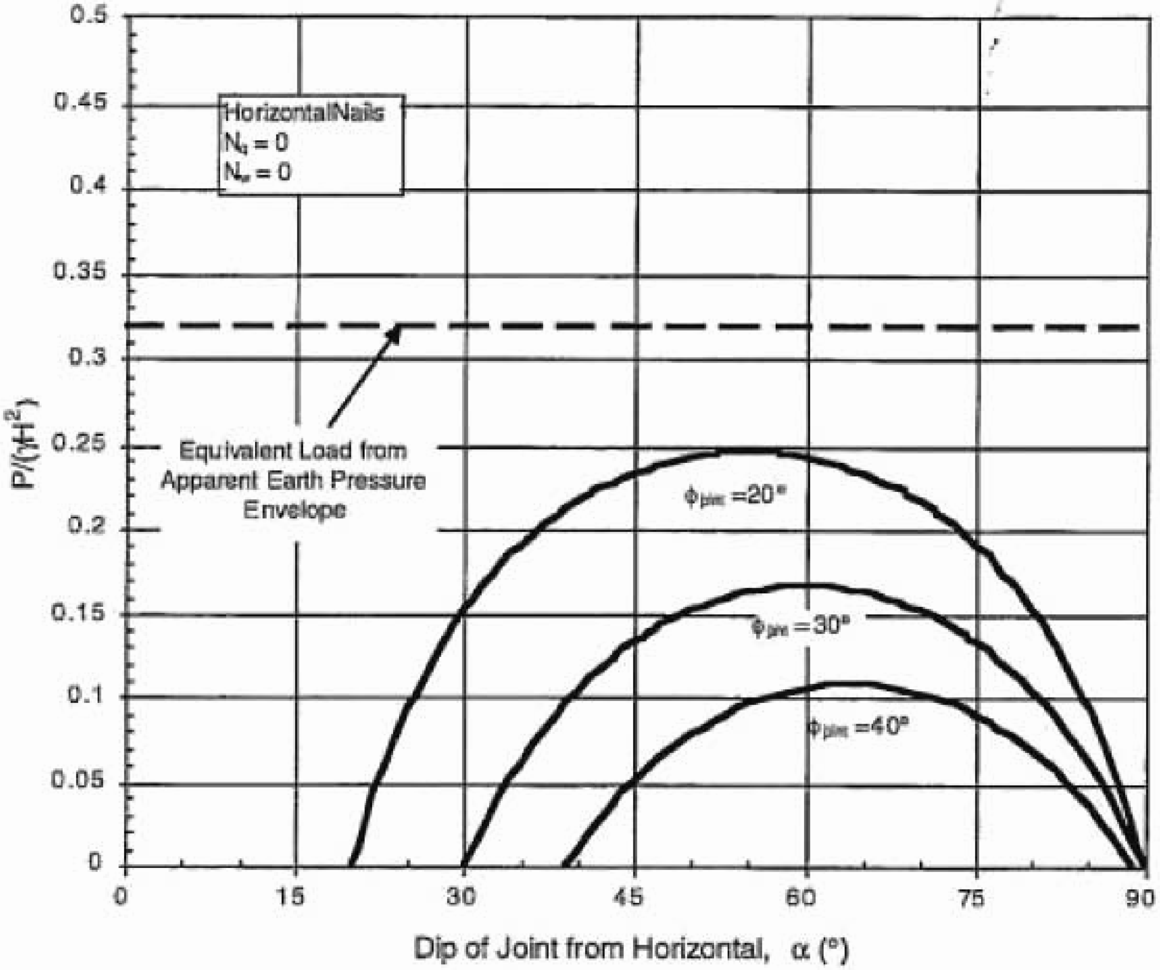


Fig. 7.5. Design Chart for Total Nail Load versus Joint Orientation.

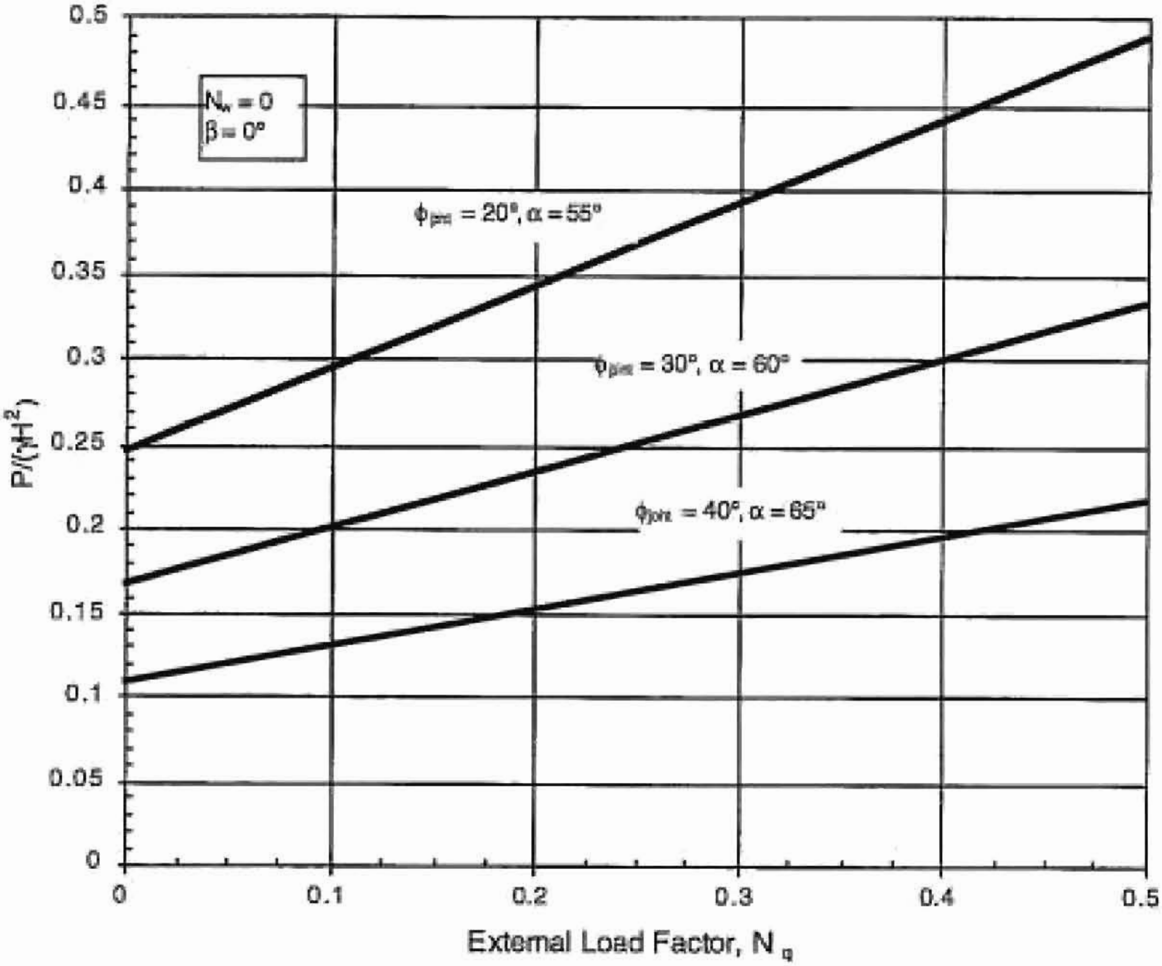


Fig. 7.6. Effect of External Loads on Total Nail Load.

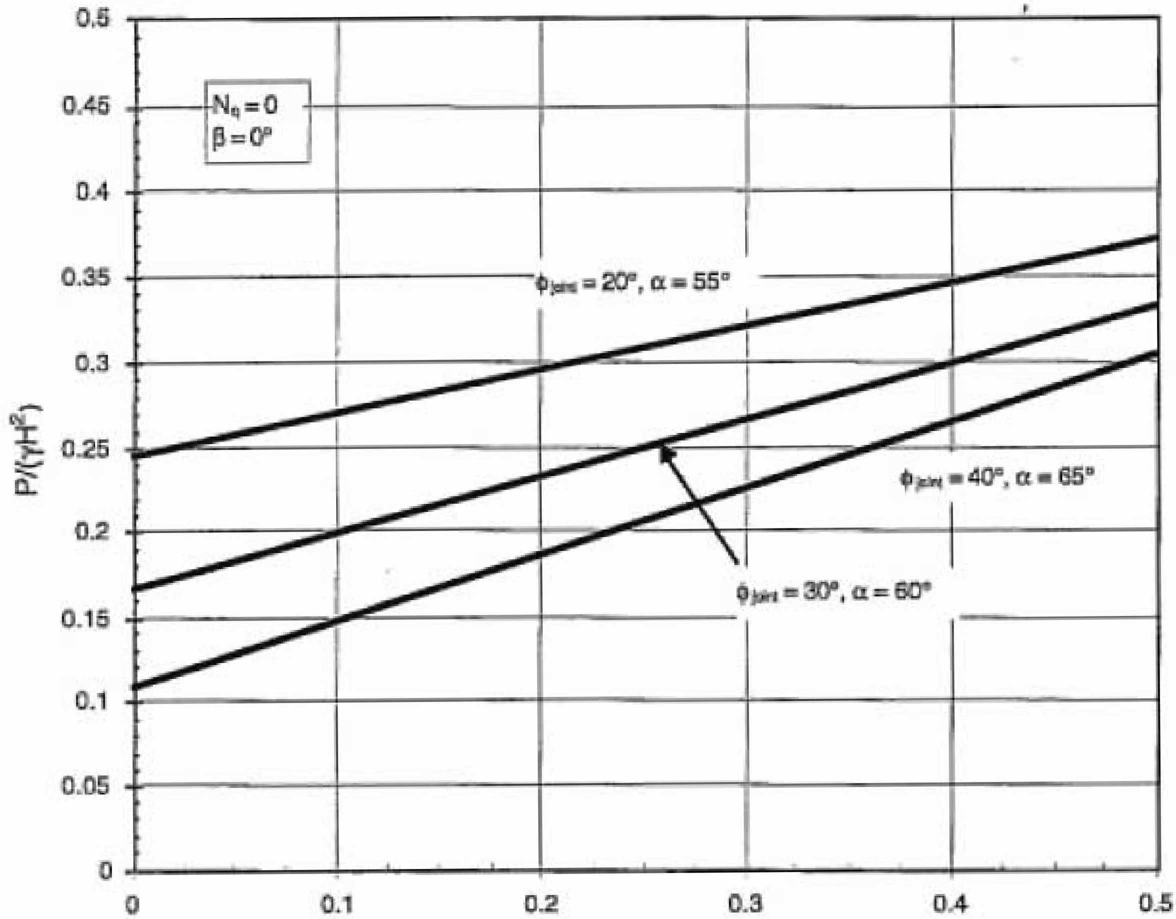


Fig. 7.7. Effect of Water Pressure on Total Nail Load.

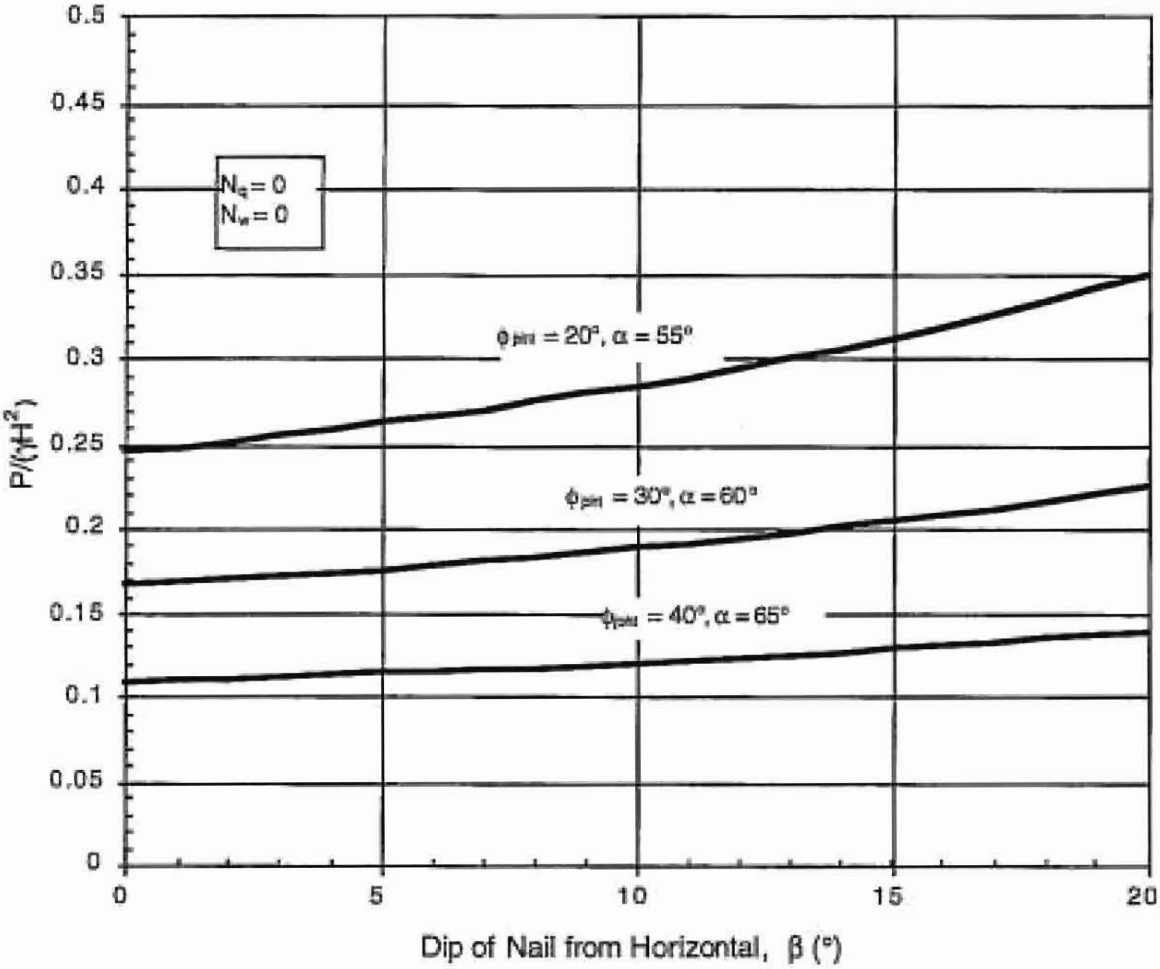


Fig. 7.8. Effect of Nail Orientation on Total Nail Load.

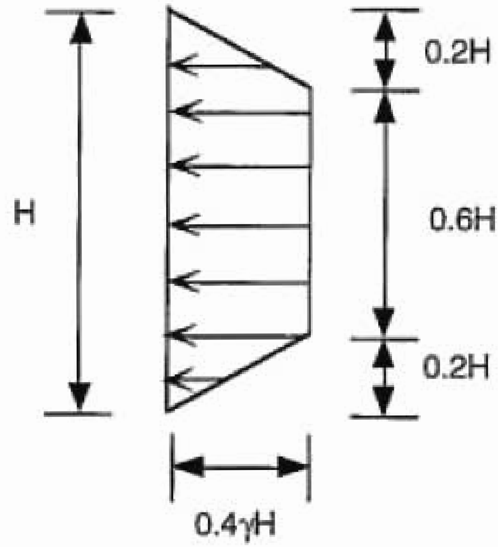


Fig. 7.9. Apparent Earth Pressure Envelope for Estimating Nail Loads.

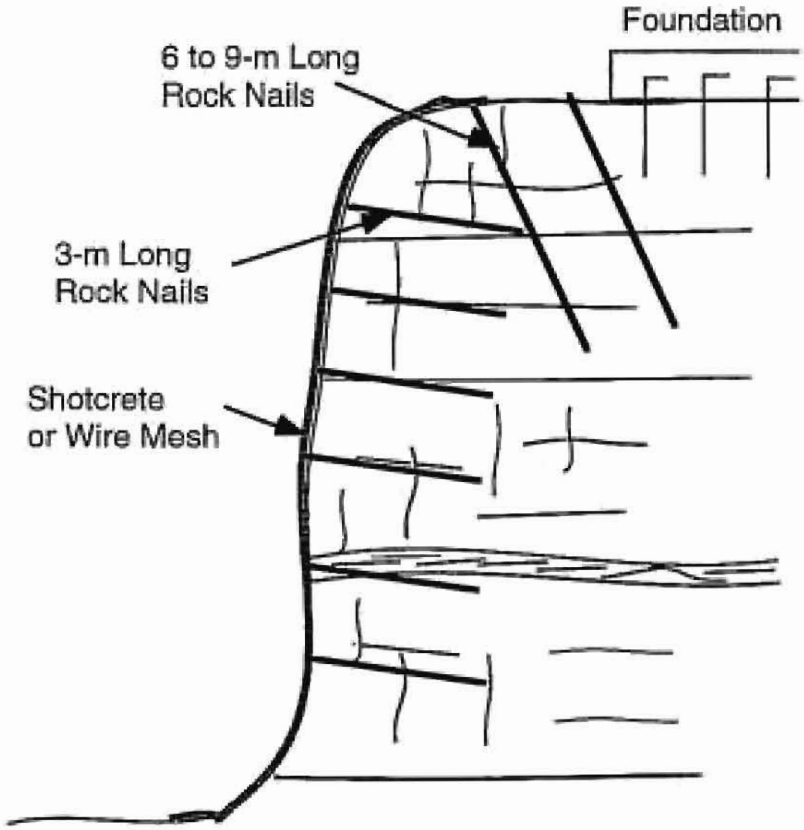


Fig. 7.10. Conceptual Nail Pattern for Local Stability of Rock Cuts Supporting External Loads (Figure Adapted from Hall et al., 1994).

CHAPTER 8. ALTERNATIVE CONTROL MEASURES FOR ROCK SLOPES

8.1 Introduction

Rock nailing is only one of many measures that are available to control the performance of rock slopes. In this chapter, alternative measures of control, which can be used alone or in combination with other measures, are described. Table 8.1 provides a list of various control measures and a summary of their respective advantages and disadvantages.

8.2 Catchment Ditches

Catchment ditches are intended to catch rockfall and prevent it from entering the roadway. Ritchie (1963), Castaneda (1976), Pfeiffer et al. (1993) and Pierson et al. (1994) all provide design guidelines for catchments. Several interesting features of these design guidelines are that (1) angled slopes require larger catchments than vertical slopes because rolling rocks develop greater momentum than falling rocks, (2) slopes with benches and ledges also may require larger catchments because falling rocks may get launched over the ditch and (3) softer rocks (i.e., UCS less than 25 MPa) require smaller catchments because softer rocks do not bounce as high. Ritchie's design catchments tend to be narrow and deep. Due to safety concerns for motorists, more recent design guidelines (e.g., Pierson et al. 1994) provide for flatter ditches, such as those typically used in Texas.

Based on the data compiled in this project (Chapter 6), a preliminary design guideline for Texas slopes with rockfall potential is that the catchment width should be approximately 0.5 times the slope height. If the catchment is sloped, than this width can be reduced. The design chart shown on Fig. 6.9, which gives required catchment width as a function of the slope height and ditch slope, provides useful guidance for typical slopes in Texas.

8.3 Catch Fences, Nets and Barriers

Rockfall catch fences and nets can be constructed at the toe of the slope to catch rolling, bouncing, or falling rocks. Fences are systems using chain link or double-twist hexagonal gabion mesh, while nets use wire rope mesh. Because they are flexible, fences and nets are able to absorb and dissipate rockfall energy without sustaining damage. They can be installed at the outside edge of the ditch or on top of barrier walls. Flexible-post and suspended-fences can also be used in the middle of longer slopes to slow rolling and bouncing rocks. The fence and net should be constructed on the outside of their supporting posts to allow easier cleaning and repair, as illustrated in Fig. 8.1. Hearn et al. (1992) provide information regarding field tests and capacity analyses on flexible-post fences. Smith and Duffy (1990) give the results of field tests on rockfall catch nets, and Duffy (1992) discusses catch-net design. Brawner (1994) gives relevant construction specifications for catch fences and nets.

Barriers are rigid structures which prevent rocks from reaching the roadway. Barriers can be built on the outside edge of the ditch to effectively increase catchment depths. The most commonly used barriers are standard Jersey barriers (concrete barriers usually used as traffic barriers). However, these are only sufficient for stopping smaller blocks (Brawner, 1994). Gabion barriers (wire mesh boxes filled with cobbles), bin walls (metal, concrete or timber bins filled with freely-draining backfill), and debris mounds have also been used effectively.

8.4 Draped or Bolted Wire Mesh

Wire mesh can be placed on the slope to prevent raveling of loose rocks and to control rock fall. Mesh can be draped over the slope to direct falling rocks to the catchment ditch. The mesh can also be attached to the rock face with small diameter rock bolts to hold loose rocks in place. Brawner (1994) recommends that these bolts should have a minimum diameter of 19.1 mm and be resin-grouted for faster installation. Also, wire mesh should be double-twisted gabion wire rather than chain-link because the latter has a tendency to unravel if one strand is broken.

8.5 Cable Lashing and Anchored Cable Nets

Cable lashing and anchored cable nets are rockfall prevention techniques used to hold unstable rock blocks or slabs in place. Cable lashing involves using large diameter, high capacity steel cables to tie down large blocks or slabs. The post-tensioned cables are attached to rock anchors outside the unstable zone. Nets of steel cable can be used to hold groups of smaller blocks in place. The net is tied to supporting cables, which are attached and tensioned as in cable lashing. Anchored cable nets can be used for blocks with diameters as large as 2.5 m.

8.6 Spot Bolting and Dowels

Spot bolting involves using bolts to support localized areas of an instability in a slope. Design loads are dependent on the forces needed to achieve equilibrium of the area being supported. The discussion on nail design presented in Chapter 7 is applicable to the design of spot bolting. In addition to their use in rock reinforcement, dowels can also be used as shear keys installed below potential sliding blocks. A common situation is shown in Fig. 8.2, where a potentially sliding block exists on a slope. As the block attempts to move, the dowel resists the movement. The dowel is packed in concrete to assure that the applied stress is in shear rather than in bending. Design loads are determined from an equilibrium analysis of the block being supported.

8.7 Shotcrete and Dental Masonry

Many of the failures in the rock slopes studied in this project are related to differential weathering and erosion. Application of shotcrete to the freshly exposed surface of the weaker layer can be used to prevent these processes. There have been some objections to the use of shotcrete on aesthetic grounds, although shotcretes with a natural appearance have been developed. In locations where aesthetics are important, reinforced masonry provides an alternative to shotcrete. While more expensive, masonry can blend in well with the surrounding rock, especially if native material is used. Reinforced masonry was used in some areas of the Fiesta Texas Theme Park, north of San Antonio (Hall et al., 1994).

8.8 Differential Erosion Buttresses

Buttresses are structures designed to support the weight of an overhanging rock block or slab that has formed from differential erosion. They are often constructed of reinforced concrete or masonry. A typical application is illustrated in Fig. 8.3. Differential erosion of marl can occur below a more resistant limestone. If a vertical joint exists or is initiated in the limestone, the weight of the undercut section can cause this crack to propagate through the entire layer, leading to a situation of block toppling. A buttress can be used to support the weight of the limestone block and, therefore, prevent toppling (Fig. 8.3).

8.9 Slope Flattening

A common means of stabilizing unstable slopes in Texas has been to flatten the slope grade. A horizontal-to-vertical slope ratio of 1H:4V is a rule of thumb used by many highway departments to determine a safe slope angle in rock (Brawner, 1994). For example, slopes of 1H:4V were excavated along RM 2222 east of Loop 360 in Austin (TxDOT, 1972). While such rules of thumb may be appropriate in some local areas for massive rocks with few discontinuities, slope instability is more often controlled by the orientation of joints within a rock mass. Additionally, rock strength and weathering characteristics are very important in the lay-back decision. Some rock units are inherently unstable on the common 1:4 slope. For example, the Eagle Ford Shale in Texas is only marginally stable at a 5H:1V slope (Allen and Flanigan, 1986). Due to weathering characteristics, other rock units may actually be more stable at steeper slopes.

The Glen Rose Limestone, for example, appears to weather faster if laid back. Fig. 8.4 shows a photograph of a slope on Spur 534 in Kerrville (1.1 km east of SH 16) at the contact between the upper Glen Rose and the Fort Terrett member of the Edwards Formation. This slope exhibits extensive erosion furrowing and slumping of the weathered material, and has not supported vegetation. At the intersection with FM 1341, about 0.32 km farther east, a retaining wall supported by 0.6 m diameter drilled shafts was constructed to retain the slumping material on a similar slope (TxDOT, 1988).

8.10 Slope Benching

Excavation of horizontal benches on slopes is another traditional method of remediating unstable slopes. Benching can improve performance in two ways. First, reducing the height of slope between benches can prevent global stability problems. The required bench height and width will be related to the rock strength and, more importantly, the orientation and location of discontinuities. Second, benches act as a mid-slope catchment for rocks which dislodge from the slope (Fookes & Sweeney, 1976) and reduce erosion by dissipating the energy of surface runoff (Piteau and Peckover, 1978).

An important consideration in designing a benched slope is that benches must be regularly inspected for accumulation of debris (usually after large rainfall or freezing events, and on a regular basis as found necessary for the particular site) and must be accessible for maintenance equipment to remove the accumulated debris. In practice, benches are often either not accessible for clearing or not cleared frequently enough. As illustrated in Fig. 8.5, filled benches can act as ramps, launching falling rocks onto the roadway. For this reason, the Federal Highway Administration has recommended that benches not be used as a form of rock slope remediation or design, and recommends their use only at the contact between rock and overburden (Brawner, 1994).

8.11 Scaling, Chemical Expanders and Trim Blasting

Periodic removal of loose, unstable or overhanging blocks from the slope through scaling, application of chemical expanders, and trim blasting can minimize rockfall potential. Scaling is the removal of smaller, usually loose, blocks on the slope. Scaling is usually done by workers on ropes using prybars, hydraulic splitters, or jacks. On some slopes, mechanical equipment like backhoes and rock breakers can be used. No studies have been done in Texas to determine how often scaling must be performed on a given rock cut. Brawner (1994) reports that, in general, scaling is usually required every 8 to 10 years where freeze-thaw is common, and every 12 to 15 years in warm, dry climates. None of the TxDOT maintenance districts contacted for this project have indicated a regular program of scaling.

Where scaling methods are not feasible, chemical expanders and trim blasting can be used. Chemical expanders are chemicals, usually inorganic lime compounds, that undergo volumetric expansion when they react. When these chemicals are placed in drill holes, the chemically-induced expansion breaks rock slowly, eliminating the rock mass damage and vibrations associated with blasting. Trim blasting is the use of small-scale explosives to remove larger blocks that are unstable or overhanging. The effectiveness of scaling, chemical expanders, and trim blasting is dependent on the quality of work. Inexperienced personnel can often cause more damage than is repaired. Brawner (1994) provides a set of sample specifications for scaling, chemical expanders and trim blasting.

8.12 Drain Holes and Surface Drainage

Slope failures are often driven by water pressures within the rock mass. Water can also cause damage through freeze-thaw (material degradation or block loosening from ice lenses) and erosion. Patterns of horizontal or inclined drain holes can be used to reduce the water table level behind a slope or to drain water-bearing discontinuities. Reduction in water pressures will help stabilize the slope and removal of water will reduce the potential for freeze-thaw damage. It is also important to control water at the surface. Piteau and Peckover (1978) recommend that ponds and water-filled depressions above the slope be drained, that the surface of the slope be reshaped to control drainage, that any cracks or permeable areas that would allow water to infiltrate the slope be sealed, and that surface drainage away from the slope be controlled by ditches and culverts. Establishing and protecting existing vegetation also reduces erosion. However, trees and large bushes should be removed from the slope and crest because they can loosen blocks through root wedging.

Table 8.1. Advantages and Disadvantages of Available Control Measures for Rock Slopes

Control Measure	Advantages	Disadvantages
Rock Nails	• Support External Loads • Improve Global Stability • Minimize Ravelinglling • Facing Can Prevent Weathering	• May be Expensive • Facing May Have Unnatural Appearance
Catchment Ditches	• Minimize Rockfall from Entering Roadway • Natural Appearance	• Wide Right-of-Way May Be Necessary • Ditch Maintenance Required • Slope Degradation from Ravelinglling and Weathering not Prevented
Catch Fences, Nets and Barriers	• Minimize Rockfall from Entering Roadway • Can Be Installed Where and When Problems Arise	• Unnatural Appearance • Slope Degradation from Ravelinglling and Weathering not Prevented • Maintenance Necessary
Draped or Bolted Wire Mesh	• Minimize Ravelinglling • Can Be Installed Where and When Problems Arise	• Unnatural Appearance • Mesh Can Corrode • Limited to Small Block Sizes (less than 1 m) • Slope Degradation from Weathering not Prevented
Cable Lashing and Anchored Cable Nets	• Minimize Ravelinglling • Block Sizes up to 2.5 m Can Be Stabilized • Can Be Installed Where and When Problems Arise	• Unnatural Appearance • May Be Expensive • Slope Degradation from Weathering not Prevented
Spot Bolting and Dowels	• Minimize Ravelinglling of Small and Large Block Sizes • Can Be Installed Where and When Problems Arise	• May Be Expensive • Slope Degradation from Weathering and Erosion May Still Occur
Shotcrete and Dental Masonry	• Slope Degradation by Weathering and Erosion Minimized • Ravelinglling May Be Minimized	• May Have Unnatural Appearance • Drainage Behind Shotcrete Can Be Problematic
Differential Erosion Buttresses	• Minimize Ravelinglling from Differential Erosion • Can Be Installed Where and When Problems Arise	• May Have Unnatural Appearance
Slope Flattening	• Prevent Global Stability Problems	• Wide Right-of-Way Necessary • Weathering and Erosion of Rock maybe Accelerated
Slope Benching	• May Improve Global Stability • May Reduce Erosion • May Act as a Mid-Slope Catchment • Can Be Installed Where and When Problems Arise	• Maintenance Required • May Launch Falling Rocks onto Roadway
Scaling, Chemical Expanders and Trim Blasting	• Minimize Rockfall due to Ravelinglling • Can Be Implemented Where and When Problems Arise	• Slope Degradation from Weathering not Prevented • May Damage Slope
Drain Holes and Surface Drainage	• Reduce Slope Degradation from Weathering and Erosion • Minimize Ravelinglling from Water Pressure and Freeze/Thaw • May Improve Global Stability	• Long-Term Maintenance and Inspection Necessary

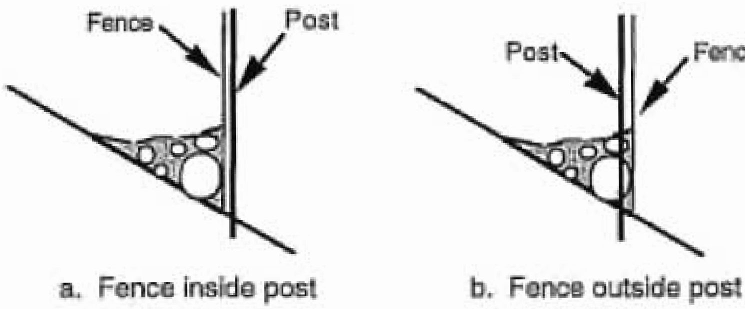


Fig. 8.1. Rockfall Catch Fence Construction.

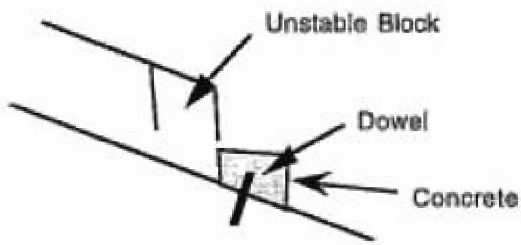


Fig. 8.2. Dowel as Shear Key.

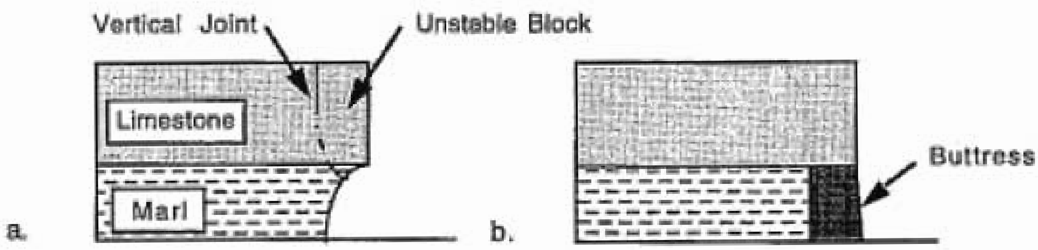


Fig. 8.3. Buttress to Support an Overhanging Block.

Fig. 8.4. Spur 534 Slope in Kerrville.

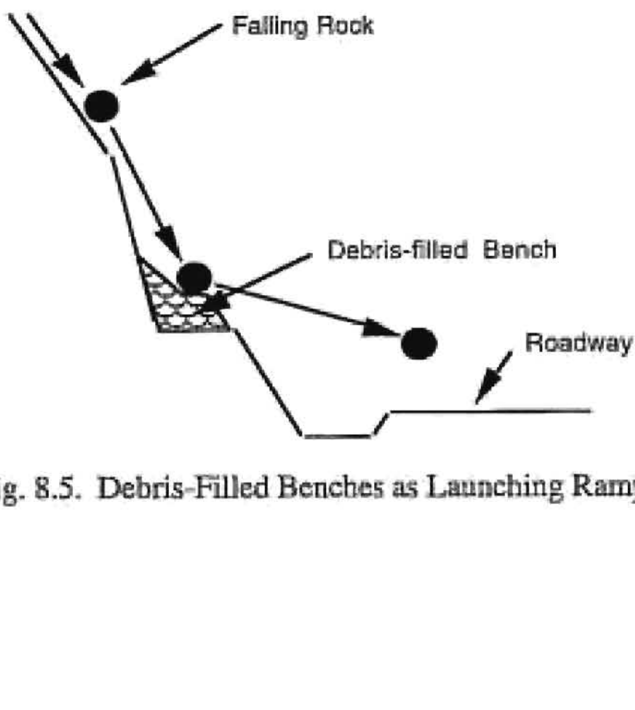


Fig. 8.5. Debris-Filled Benches as Launching Ramps.

CHAPTER 9. CONCLUSIONS AND DESIGN RECOMMENDATIONS

9.1 Summary

The objective of this project was to develop a rational design procedure for road cuts in the soft rocks of central Texas. A comprehensive field reconnaissance was conducted, and the behavior and characteristics of the rocks in natural and man-made exposures were systematically observed and documented. The rock units in this study have included primarily the Cretaceous-age sedimentary rocks that outcrop in a broad band from west of San Antonio through Austin, Waco and Dallas. The lithologies include limestones and dolostones of varying purity, through clay-rich marls and clay shales.

Observations have included exposure geometry, rock mass quality, impact of weathering, and potential failure modes. Rock cores were also obtained and laboratory tests were conducted on core samples and grab samples from exposures. In addition, the performance of existing excavations and design procedures was also evaluated. Performance information that was collected and analyzed included qualitative descriptions of stability, quantitative information on maintenance frequency and effort, and quantitative information on catchment adequacy. The major conclusions from this work are summarized in the following section, and design recommendations are provided in the final section of this chapter. The methodology developed here can be applied to other geologic formations encountered in TxDOT construction.

9.2 Major Conclusions

Failure Modes: The most common mode of failure in road cut exposures has been localized raveling and differential erosion. The Cretaceous-age rocks in central Texas contain varying amounts of clay, making them susceptible to disaggregation under the wet/dry cycling that is characteristic of the central Texas climate. Units that contain clay-rich rocks weather and erode very rapidly on exposure. As weathering proceeds, the more resistant units are left as tables or cantilevered overhangs that eventually break off. This failure mechanism is particularly dominant in the Glen Rose Formation and the Austin Chalk. Raveling of loose blocks is associated with the Edwards Formation where paleokarst and recent (in geologic time) solutioning has created cavities and fractures. The block sizes in both instances tend to be comparable in dimension to the bedding thickness, on the order of 0.5 m. Increased weathering and block fallout are associated with groundwater seepage from the cut or overland run-off flowing down the cut surface. For excavations in uniform, layered rock, differential weathering is less of a problem because the rock face weathers uniformly.

Large-scale planar or wedge failures due to continuous, steeply dipping discontinuities are not common in central Texas road cuts. This failure mode was observed in only 3 of the 53 road cuts studied. In all cases, these failures were associated with faulted zones within the Glen Rose Formation. While localized raveling and differential erosion could eventually lead to larger-scale failures, this type of failure was not observed in any of the road cuts; hence, the time required to achieve such a failure is probably greater than 50 years.

Performance versus Formation: Cuts in the Edwards Formation are generally more stable than those in the Glen Rose or Austin Chalk. For the Glen Rose, the upper 10 to 15 m can have highly variable properties and low strengths due to weathering and the presence of marls. Shallow cuts that are laid back can actually weather into soil-like materials that eventually exhibit slumping. Weathering of the Edwards is much less pronounced than for the Glen Rose or Austin Chalk. The main source of variability in the Edwards is related to solutioning and collapse zones; these zones tend to ravel more readily and require greater maintenance than unsolutioned zones.

Predicting Performance: Conventional information from borings provides limited information in predicting the performance of rock cuts in central Texas. The quality of the rock core (i.e., the rock quality designation, RQD) does not correlate well with stability. While high RQD values are generally associated with good performance, low RQD values are not necessarily associated with poor performance. For example, the Edwards Formation generally had the lowest core quality, yet the slopes are performing the best because rock matrix in solution collapse zones fractures readily when cored but is cemented in situ. It is especially important in these rocks to use high-quality coring techniques to minimize damage to the core sample during drilling. Borings may be useful in detecting marl layers in the Glen Rose. These layers can lead to significant problems from weathering and differential erosion.

In general, existing rock mass classification schemes such as the Rock Mass Rating (RMR) and the Slope Mass Rating (SMR), are not effective at predicting the performance of the soft rocks in central Texas. These schemes, which were developed over the past 20 years by correlating performance with rock properties and conditions, are most appropriate for rock masses where failure modes are driven by discontinuities and joints. Since the most common failure mode for the central Texas rock cuts is localized raveling and degradation, these conventional schemes are not appropriate.

Raveling and differential erosion are characterized by layered rock units with large differences in weathering resistance. It was found that differences in slake durability of greater than 20 to 30 percent between individual layers within a slope indicate a high potential for differential erosion. However, the absolute magnitude of slake durability, or other related properties such as unconfined compressive strength, are not effective indicators of this failure mode.

Maintenance Requirements: Maintenance requirements tend to be greater for cuts susceptible to raveling and differential erosion, cuts with groundwater seepage, and taller cuts. Benches can be effective at reducing the slope height and, therefore, reducing the maintenance requirements. However, benches are only effective if they are wide enough to catch rock fall from the slope above and are cleaned frequently. Several of the studied slopes, specifically along Loop 360 in Austin, have benches that are filled with debris and cannot be accessed for cleaning. Filled benches are problematic because subsequent rock fall will not be caught, and blocks may be projected out further from the slope toe and closer to the road.

Catchment Adequacy: Flat catchments to collect rock fall are effective if the width is greater than one-half the slope height. Increasing the grade of the catchment toward the slope can provide an effective catchment at narrower widths. Also, cuts that are not susceptible to raveling and differential erosion perform well even with narrow catchment areas because rock fall is not a problem.

Drainage: Water seepage and pressures can lead to rock mass deterioration. It is therefore important to maintain open drainage behind facing or walls.

Rock Nail Performance: The few rock cuts containing rock nails have all performed well to date. The nails and facing materials have prevented raveling and erosion that has occurred in other cuts at the same sites.

9.3 Design Recommendations

Design recommendations for road cuts in rock are provided in the following sections. These recommendations pertain specifically to the soft rocks of central Texas that were studied in this project.

9.3.1 Site Investigation

Site investigation is an important step in developing a design for a cut slope in rock. The following preliminary information should be obtained at a minimum from the investigation:

- stratigraphic information, including formation type;
- bedding thickness;
- presence of voids or soft, weathered zones; and

- presence, dip and orientation of joints or other discontinuities.

In general, this information can be obtained from published geologic maps and literature, local experience, the data included in this report, and a field reconnaissance of the site and vicinity.

On the basis of this preliminary information, further investigation is recommended in the following instances:

1. If a potentially continuous discontinuity trends nearly parallel to the slope face and dips toward the cut, the orientation, dip and roughness of the discontinuity should be investigated. Borings are one possible approach, although they will only detect discontinuities with dips less than about 70° unless the borings are inclined. Shallow geophysical techniques might also be used to locate and orient these features. At a minimum, a more detailed field reconnaissance is warranted to identify the possible orientation and dip of these features. If continuous discontinuities are expected, site inspection by qualified geologists or geotechnical engineers should be planned during construction.
2. If a slope in the Glen Rose or Austin Chalk is to be unsupported and the catchment area will be less than 0.5 times the slope height, then the potential for differential weathering and erosion should be investigated. Borings should be drilled to identify if thick (greater than 0.3 m) marl layers are present. Also, slake durability tests should be conducted on core samples to determine the difference in slake durability between individual layers in the proposed cut. If thick marl layers are present or the difference in slake durability exceeds 20 percent, then some form of face support is recommended.
3. If a slope is to be supported with rock nails, then borings are recommended to estimate the thickness of beds and to identify anomalies, such as collapse features or soft, erodible layers of rock. Unconfined compression tests are also recommended on core samples to provide information on nail capacity.

Borings that are drilled should be drilled with double or triple tube core barrels using a diamond insert cutting bit. Percent recovery and RQD should be documented for each core run. Percent recovery is useful in identifying collapse features, fault zones and soft, erodible layers.

9.3.2 Rock Cut Design Recommendations

In most instances, near-vertical, 10 to 30-m high rock slopes or cuts in these formations can be left unprotected and unsupported if an adequate catchment area at the toe is provided to prevent rockfall from entering the roadway. A flat catchment area should be at least 0.5 times the slope height in width; catchments graded back toward the slope can be narrower, and the design chart included in Fig. 6.9 of this report is recommended for their design. Benching to decrease the effective slope height is not recommended unless the benches are made wide enough to catch falling debris (again, a bench width on the order of 0.5 times the bench height is recommended) and can be accessed for clean out. Cuts that are flatter than near-vertical (i.e., less than 70° from horizontal) are not recommended, because the reduction in drainage efficiency tends to promote weathering, especially in the Glen Rose Formation.

In areas where adequate catchment cannot be provided due to right-of-way or other geometrical constraints, the slope should be protected from raveling and differential erosion. The preferred approach for protection is a 100-mm thick layer of fiber reinforced shotcrete. Adequate drainage should be provided behind the shotcrete. Draped or bolted wire mesh is an alternative approach that may be less expensive and more pleasing visually; however, it will probably not be as effective as shotcrete at minimizing differential erosion. Spot bolting (or nailing) is recommended for supporting larger blocks (on the order of several meters in size) that may be unstable. Seepage and surface water control will also be helpful in minimizing raveling and erosion.

In areas where external loads are to be supported near the crest of the rock cut, rock nails are recommended in addition to the shotcrete. The rock nails in the face should be 25-mm diameter steel bolts ($f_y = 420$ MPa) grouted in 75-mm diameter boreholes, oriented near horizontal, spaced at 1.5 m horizontally and vertically, and 3-m in length. Additional rock nails should be installed near the slope crest if the external loads are large (e.g., a bridge abutment foundation). These nails should be oriented at about 60° to the horizontal and at least 3 times the foundation width in length.

If continuous, steeply dipping discontinuities will daylight at the cut face, then rock nails (or tiebacks) should be installed across the discontinuity to support the potentially unstable wedge. This recommendation is intended for both slopes with and without external loads if a large-scale planar or wedge failure is possible. A design equation and design charts are presented in Chapter 7 to estimate the required nail loads. The nails should be similar to those described above, except that they should be fully encapsulated in a plastic sheath to minimize corrosion. Again, fiber reinforced shotcrete should be applied at the cut face to prevent localized raveling and differential erosion. Drainage should be provided behind the shotcrete and within the slope to prevent build up of water pressures.

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APPENDIX A

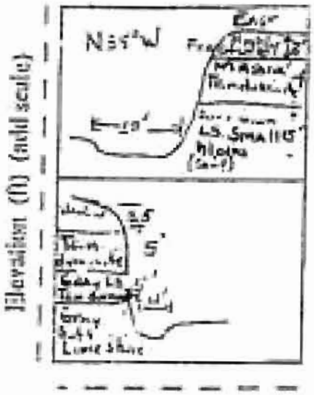
Field Data Forms

List of Field Reconnaissance Data F

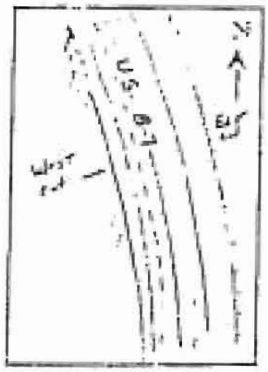
Site Code	Location	No. of Pages
360-1	Loop 360, N. of RM 2222	4
360-2	Loop 360, at RM 2244	4
360-3	Loop 360, 1.6 km N. of Wild Basin Road	4
620-1	RM 620 at Mansfield Dam	7
620-2	RM620 S. of Lakeway	3
2244-1	RM 2244 at Crystal Creek Road	4
2244-2	RM 2244 at Addie Roy Road	4
SWP-1	Southwest Parkway, E. of US 71	4
SRR-1	Steiner Ranch Road at Quinlan Park Road	4
Au-1	RM 2222 between Loop 360 and Mopac	4
Au-2	Rm 2222 at Loop 360 drainage channel	4
Au-3	Lake Georgetown Spillway	4
Au-4	US 87, N. of Mason	4
D-1	Loop 303, E. of Loop 12	4
D-2	IH 30 at Hampton Road	4
D-4	FM 1382, Cedar Hill	4
D-5	New Clark Rd. at FM 1382	4
FW-1	US 377 between Granbury and Cresson	2
FW-1	SH 16, W. of SH 337	3
281-1	US 281, S. of Cibolo Creek	4
281-2	US 281 at Belverde Estates	4
281-3	US 281, just S. of SH 46	4
281-4	US 281, 7.9 km S. of Guadalupe	4
281-5	US 281, just N. of 281-2	4
1376-1	FM 1376, N. of Boerne	4
1376-2	FM 1376, S. of FM 473	4
I-10-5	IH-10 near FM 289	4
2722-1	FM 2722 between FM 2673 and SH 46	4
2673-1	FM 2673 at FM 2722	4
3159-1	FM3159 N. of SH 46	4
I-10-1	0.8 km E. of SH 16	4
I-10-2	2.4 km E. of SH 16	4
I-10-3	IH 10 at Cypress Creek	4
I-10-4	IH 10, just W. of Cypress Creek	4
I-10-6	IH 10, 1.6 km W. of Sh 16	4
I-10-7	IH 10, 1.6 km W. of FM 783	4
I-10-8	IH 10 just E. of FM 1338	4
I-10-9	IH 10 in Gillespie Co.	4
41-1	SH 41 at SH 27	4
187-1	FM 187, N. of Lost Maples State Park	4
337-1	RM 337 at Mill Creek	4
337-2	FM 337, top of Mill Creek Pass	4
470-1	FM 470, Tarpley Pass	8
211-1	SH 211, N. of FM 471	4
211-2	SH 211, N. of Bexar Co. Line	4
211-3	SH 211, S. of SH 16	5
1283-1	FM 1283 at CR 270	4
1283-2	FM 1283, 1.4 km S. of Park Road 37	4
173-1	FM 173 S. of Bandera-Medina Co. Line	4
S-1	Loop 1604 at Bitters Road	4
S-2	Loop 1604 at Gold Canyon Road	4

TxDOT Rock Mass Field Description

Code Av-4
Page 1 of 4



Profile Sketch



Plan/Map Sketch

Field Crew: MG BM

Date: 5-25-94

Location: US 87 [illegible]

TxDOT District: 14 [illegible]

Geologic Formation: [illegible]

[illegible]

General Exposure Description

Dimensions and Orientation

Total height (ft) 35' West 25' East

Lateral Extent (ft): [illegible]

Benches: number of levels: 2 height (ft): ______ width (ft) ______

Face orientation: strike/dip N 35° W

Catchment Description: [illegible]

Support Installed: None

Method of Excavation (if blasted, describe blast effects) Blasted [illegible]
highly weathered [illegible]

Age of Exposure 30-40 years

Vegetation Effects None

Elevation (ft) (add scale)

Elevation Sketch of Exposure (ft) (add scale)

TxDOT Rock Mass Field Description
Glen Rose Formation

Summary of Engineering Geologic Data

Joint Description Summary

Set #	Strike	Dip	Roughness	Separation/ Filling	Persistence	Weathering	Remarks
1	N85°E–N46E	90°	P.R.	TITL	MOSTLY P	1b	[illegible]
2	N75E	65°	P.R.	TITL	NP	1b	[illegible]
3	N60W	80°	P.R.	TITL	NP	1b	CONN BET 2 UNIT (90%)

Other Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks

Occasional Random Joints? YES DC

Bedding Description: GENERALLY MASSIVE w/ OCC. BEDS < 1' THICK

Weathering/Erosion: MARLY BED 3' THICK 6' ABOVE BASE (SEVERE EROSION)

Form of Slope Failure/Degradation: BLOCK/RUBBLE FAILURE GRADUALLY ALONG MARL LAYER RESULTING IN SMALL ROCK BENCH

Debris: MASSIVE AMT OF DEBRIS ON BENCH (SILT TO 2' BOULDER SIZE) NOT MUCH DEBRIS IN CATCHMENT LOOKS LIKE IT BEEN CLEANED SILT TO 1' BOULDER SIZE

Maintenance Record: ?

Available Geotechnical Data: ?

TxDOT Rock Mass Field Description

Glen Rose Formation

Scanline Descriptions

Horizontal Scanline Number: 1
Horizontal Location (locate on sketch): ENTIRE CUT
Height above base of cut (ft): FACE
If w/in one layer, layer thickness: —
Length of scanline (ft): 1000'
Strike of scanline (if different from face): ____________

0+00 0+50 1+00

Scanline Sketch (include seepage locations)

Debris Description

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Condition
			+/-20	20-45	45-90	R/L	+/-20	20-45	45-90	R/L		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												

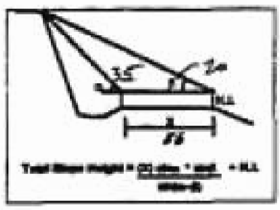
Set	Apparent spacing (#/scan length)	True Spacing (#/scan length)
1	25'	11'
2	200'	180'
3	56'	53
4		
5		

TxDOT Rock Mass Field Description

Glen Rose Formation

Scanline Descriptions

Vertical Scanline Number: ________
Scanline Location (show on sketch): ________________
Height of Scanline (ft): ________
Length of Scanline(ft): ________



+ DITCH = 75'

Fracture frequency: ________
Est. RQD: ________

Scanline Sketch

Scanline Information:

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Cond'n
			+/-20	20-45	45-90	R/L	+/-20	20-45	45-90	R/L		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												

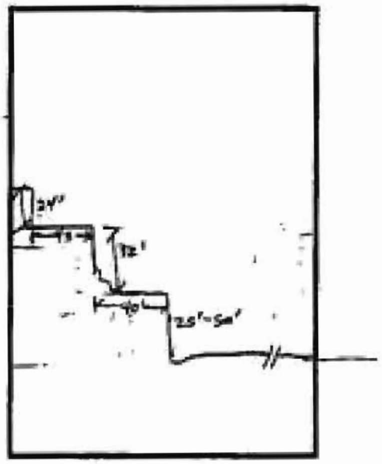
Date: 6/21/95
Page 1 of 4
Code 360-2

TxDOT Rock Mass Field Description

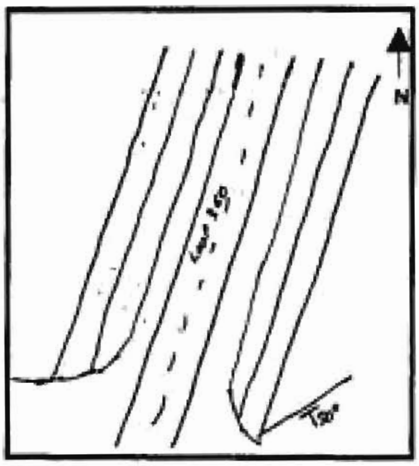
Formation: GLEN ROSE / EDWARDS

Location: Loop 360 just North of RR 2244

TxDOT District: AUSTIN



Profile Sketch



Plan Sketch

General Exposure Description

Dimensions and Orientation:

Total Height (ft): 81'

Lateral Extent (ft): 1300'

Benches: 2

	Height	Width
L1	24	45
L2	32	40
L3		

Face Orientation: Strike/dip: N 5° E 75°–84° (10°–12° LAYBACK)

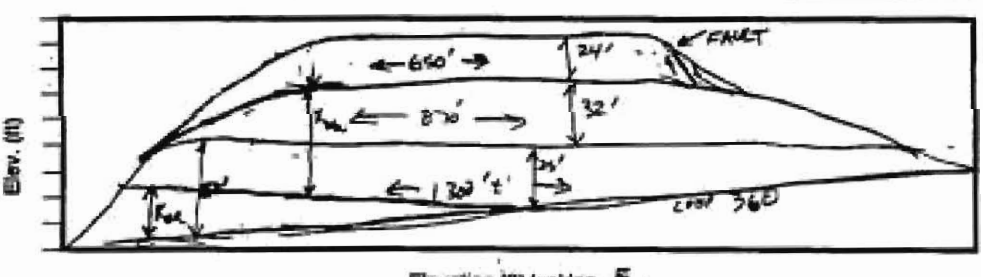
Catchment Description: SET BACK 20'–25'

Artificial Support: NONE

Method of Excavation (incl. effects): BLAST

Age of Exposure:

Vegetation Effects: NONE



Elevation (ft) looking E.

TxDOT Rock Mass Field Description

Summary of Engineering Geologic Data

Joint Description Summary

Set #	Strike	Dip	Roughness	Separation/ Fitting	Persistence	Weathering	Remarks
No JTS							
1 JT	N45°E	90	R/P	TITL	P	II	DRY
1 JT	N60°E	45°NW	S/P	TITL	P	Ib	DRY
1 JT	N45°W	45°SE	SS/P	TITR	P	II	DRY
1	DR. EAST	90°	NR/U	TITL	P	II	DRY [illegible] / [illegible] WET

Other Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks
FAULT	N65°E	50°SE	SS/R - P	[illegible]	[illegible] end of slope, 2' OFFSET

Occasional Random Joints?

Bedding Description: TOP: HARD Kea, 3'-8', VUGGY, OCC lg. void 2'±
MIDDLE: SOFTER LS, MARL (FOSSILIFEROUS) 3'-6' BEDS', OCC. WET SPOT IN MARL LAYER
BOTTOM: K[illegible]; (UPPER 25) is 1'-5' [illegible]. K[illegible] (LOWER 25') IS 1"-2' [illegible] BEDS
NO MARL BEDS.

Weathering/Erosion: TOP: NONE
MIDDLE: MAJOR
BOTTOM: NONE

Form of Slope Failure/Degradation: TOP: V. MINOR SPALLING OF BOTTOM BED.
MIDDLE: MAJOR SPALLING/RAVELING OF K[illegible] FORMATION
BOTTOM: BLOCK FALL MOSTLY FROM TOP. LOOSE BLOCKS AT SLOPE [illegible] (TYP) LG. BLOCK SPALLING

Debris: TOP BENCHES V. LITTLE, SMALL < 6"
MIDDLE " : LG. AMOUNT OF DEBRIS: FORMED TALUS PILES @ TOE OF SOIL TO 5' BLOCK SIZE
BOTTOM: COBBLE TO 2' BOULDERS IN DITCH AT TOE. NOTHING CLOSE TO ROAD

Maintenance Record:

Available Geotechnical Data:

TxDOT Rock Mass Field Description

Scanline Descriptions

Horizontal Scanline Number: ____
Horizontal Location (locate on sketch): ____________
Height above base of cut (ft): ____
If w/in one layer, layer thickness: ______
Length of scanline (ft): ______
Strike of scanline (if different from face): ____________

0+00 0+50 1+00

Scanline Sketch (include seepage locations)

Debris Description

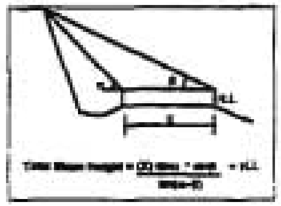
obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Condition
			+/-20	20-45	45-90	R/L	+/-20	20-45	45-90	R/L		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												

Set	Apparent spacing (#/scan length)	True Spacing (#/scan length)
1		
2		
3		
4		
5		

TxDOT Rock Mass Field Description

Scanline Descriptions

Vertical Scanline Number: ________
Scanline Location (show on sketch): ________
Height of Scanline (ft): ________
Length of Scanline(ft): ________



Scanline Sketch

BEST RQD
TOP - 90-100
MID 60-75
BOTTOM - 80-/100

Photo Listing

No.	Description
1	PAN LEG ~~[illegible]~~ NE
2	PAN LEG ~~[illegible]~~ NNE
3	PAN LEG NW
4	UPPER BENCH LEG SW
5	" " LEG NE
6	FAULT, TOP SLOPE
7	DEBRIS, ~~[illegible]~~ MIDDLE BENCH
8	LOOSE SECTION READY TO SPALL
9	TALUS, MID BENCH
10	DEBRIS MIDDLE BENCH
11	DISINTEGRATED/WEATHERED BOULDER
12	DEBRIS BOTTOM DITCH

Samples Taken: SAMPLE FOR SCANS FROM FOSSILIFEROUS WALL BED IN Kea

13 - CRACK BEHIND FACE
14 - CONTACT BTWN Kui/Kea

Scanline Information:

obs #	Sta.	Set	Strike w/r to exposure +/-20	20-45	45-60	R/L	Dip w/r to exposure +/-20	20-45	45-60	R/L	Persist.	Cond'n
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

Date: 6/24/95
Page 1 of 4
Code 360-3

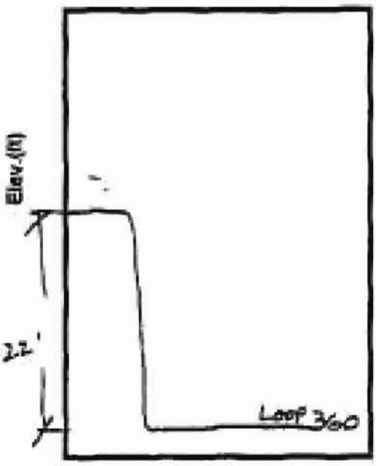
TxDOT Rock Mass Field Description

Formation: GLEN ROSE

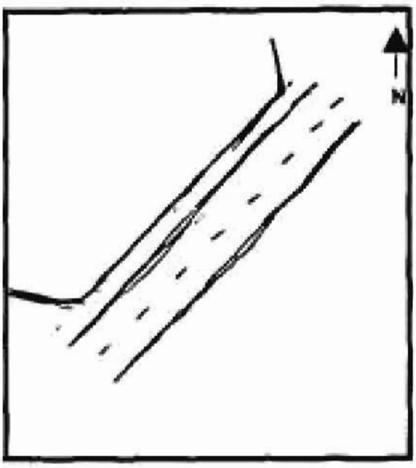
Location: LOOP 360 ONE MILE N. OF WILD BASIN RD

TxDOT District: AUSTIN

EAST SIDE (SOUTHBOUND)



Profile Sketch



Plan Sketch

General Exposure Description

Dimensions and Orientation:

Total Height (ft): 22'

Lateral Extent (ft): 390'

~~Benches:~~ Height Width

L1

L2

L3

Face Orientation: Strike/dip: N55°E 85°

Catchment Description: SET BACK 20-25' FROM EOP

Artificial Support: NONE

Method of Excavation (incl. effects): BLAST - SMOOTH WALL

Age of Exposure:

Vegetation Effects:

Elevation (ft) looking NW

Page ___ of ___
Code ________

TxDOT Rock Mass Field Description

Summary of Engineering Geologic Data

Joint Description Summary

Set #	Strike	Dip	Roughness	Separation/ Filling	Persistance	Weathering	Remarks
1	N 15° E	90°	V. ROUGH	VARIES	P	II – III	SEE SCANLINE
2	DUE EAST	85° N	V. ROUGH	TIGHT → WIDE	P	II	SEE SCANLINE

Other Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks

Occasional Random Joints? ________

Bedding Description: LOWER 10' 4" – 2' HARD NODULAR FOSSILIFEROUS BEDS UPPER 12' IS 2'–4' HARD BEDS
NORTH 100'–150' HAS HIGHLY FRACTURED BEDS IN LOWER 1/2 OF SLOPE
NO MARLY BEDS

Weathering/Erosion: NONE

Form of Slope Failure/Degradation: V. MINOR SPALLING; OCC. BLOCK @ N. END

Debris: V. LITTLE COBBLE SIZE

Maintenance Record: ________

Available Geotechnical Data: ________

TxDOT Rock Mass Field Description

Scanline Descriptions

Horizontal Scanline Number: 1
Horizontal Location (locate on sketch): WHOLE CUT
Height above base of cut (ft): N/A
If w/in one layer, layer thickness: ________
Length of scanline (ft): 390'
Strike of scanline (if different from face): SAME

0+00 0+50 1+00
Scanline Sketch (include seepage locations)

Debris Description

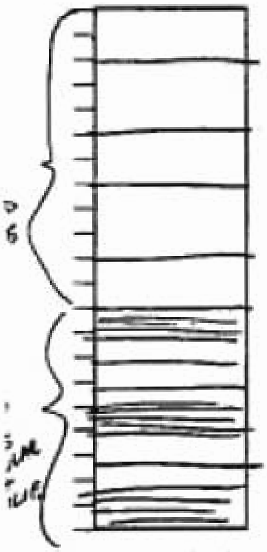
obs #	[illegible]- PACES/FT	Set	Strike w/r to exposure +/-20	20-45	45-90	R/L	Dip w/r to exposure +/-20	20-45	45-90	R/L	Persist.	Condition
1	1	1		X		L	X			N/A	P	VR/U/TITE/II/DRY
2	13	1		X		L	X			N/A	P	VR/U/TITE to 10mm/II/DRY
3	21	1		X		L	X				BOTTOM 10'	VR/U/TITE/Ia/DRY
4	[illegible]	1		X		L	X			N/A	TOP 10'	VR/U/TITE/Ib/DRY
5	33	1		X		L	X			N/A	P	VR/U/TITE → 1/2in./II/DRY/FALL IN
6	43	1		X		L	X			N/A	P	VR/U/TITE → 10mm/II/DRY/- FILL
7	53	1		X		L	X			N/A	P	VR/U/TITE/II/DRY
8	64	1		X		L	X			N/A	P	VR/U/2"-3"/III/SOIL FILL/GRASS
9	75	2		X		R	X			N/A	P	VR/U/TITE-10mm/II/NO FILL/DRY
10	77	1		X		L	X			N/A	P	VR/U/2"-3"/II/FALL IN ROCKS/DRY
11	87	1		X		L	X			N/A	P	VR/U/TITE/II/NO FILL/DRY
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												

Set	Apparent spacing (#/scan length)	True Spacing (#/scan length)
1	40'	20'
2	RANDOM	1/SLOPE
3		
4		
5		

TxDOT Rock Mass Field Description

Scanline Descriptions

Vertical Scanline Number: ________
Scanline Location (show on sketch): ________
Height of Scanline (ft): ________
Length of Scanline(ft): ________



Scanline Sketch

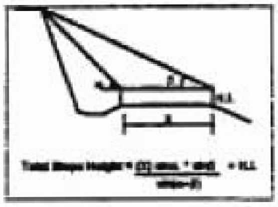


Photo Listing

No.	Description
16	DAM LKG SW
17	JTS LKG NW
18	JTS LKG N
19	

Samples Taken: NONE

BST. RQD.
UPPER 12' 90'–100'
LOWER 10' 60'–70'

Scanline Information:

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Cond'n
			+/-20	20-45	45-90	R/L	+/-20	20-45	45-90	R/L		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

TxDOT Rock Mass Field Description

Code AV-4
Page 2 of 4

Summary Geologic Description

Bedding Description: Strike/dip: ________

Layer	Thickness	Geologic Formation	Physical Properties	Remarks	Samples Taken
1	3.5	Edwards	[illegible]		
2	5		[illegible]		
3	5		[illegible]		
[illegible]	[illegible]		[illegible]		

Joint Description Summary

Joint Set	Strike	Dip	Condition	Persistence

Major Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks

Differential Weathering: of Marly beds resulting in [illegible]

Active Erosion: N/A

Geotechnical Data (core available, site investigation report?): None

Form of Slope Degradation: Raveling, differential weathering

TxDOT Contact: [illegible]

TxDOT Record of Maintenance:

TxDOT Rock Mass Field Description

Code AU-4
Page 3 of 4

Scanline Descriptions

Horizontal Scanline Number: ___

Horizontal Location (key into profile sketch and elevation sketch): ________

Height above base of cut (ft): _______

If within one layer, layer thickness (ft): _____

Length of scanline (ft): _____

Strike of scanline: _________

No Jointing Noted

0+00 0+50 1+00

Scanline Sketch (stationing in ft, include seepage locations)

Small blocks, stable

Debris Description

Scanline Information:

Obsⁿ	Station	Set	Strike (w/r to exposure)				Dip (w/r to exposure)				Persist	Cond'n	Remarks
			±20°	20-45°	45-90°	R/L	±20°	20-45°	45-90°	R/L			
1													
2.													
3													
4													
5													
6													

Description Keys:

Strike or Dip: R = into slope to the right
L = into the slope to the left

Condition: Closed: rough, undulating, planar, slickensided
Filled: sandy, clayey, *gouge*, filling thickness

Persistence: exposed length (ft), continuous through outcrop, bed-confined, termination index: T, S, R

Debris: Estimated block size (ft), *Joint or blast formation*, Differential Weathering

TxDOT Rock Mass Field Description

Code A-4

Scanline Descriptions

Vertical Scanline Number: 1

Scanline Location (key into profile sketch and elevation sketch): ________

Height of scanline (ft): _____

Length of scanline: ________

Elevation (ft) (add scale)

RQD Estimated from [illegible]

Scanline Sketch

Scanline Information:

Obs^n	Station	Set	Strike (w/r to exposure)				Dip (w/r to exposure)				Persist	Cond'n	Remarks
			±20°	20-45°	45-90°	R/L	±20°	20-45°	45-90°	R/L			
1													
2													
3													
4													
5													
6													

Fracture Frequency (disc/ft): _____

Estimated RQD: [illegible]

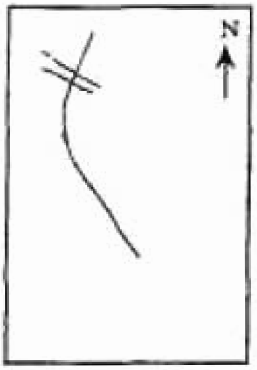
TxDOT Rock Mass Field Description STRIDE 2.8' **Code** Av-3

Page 1 of 4

Elevation (ft) (add scale)

Vazzable

Profile Sketch



Plan/Map Sketch

Field Crew: M. GALVAN
B. MOSES, P. NELSON
Date: 3/14/94
Location: LAKE GEORGETOWN
TxDOT District: ____
Geologic Formation: EDWARDS

General Exposure Description

Dimensions and Orientation

Total height (ft) 40-45'

Lateral Extent (ft): ____

Benches: number of levels: ____ height (ft): ____ width (ft) ____

Face orientation: strike/dip ____

Catchment Description: NONE BLOCKS WITHIN 5-10' OF BASE

Support Installed: NONE

Method of Excavation (if blasted, describe blast effects) BLASTED

Age of Exposure 1972-1950? 22 YRS?

Vegetation Effects ____

Elevation (ft) (add scale)

Elevation Sketch of Exposure (ft) (add scale)

TxDOT Rock Mass Field Description

Code Av-3
Page 2 of 4

Summary Geologic Description

Bedding Description: Strike/dip: ________

Layer	Thickness	Geologic Formation	Physical Properties	Remarks	Samples Taken

Joint Description Summary

Joint Set	Strike	Dip	Condition	Persistence

Major Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks

Differential Weathering: ________

Active Erosion: ________

Geotechnical Data (core available, site investigation report?): ________

Form of Slope Degradation: ________

~~TxDOT~~ Contact: COE?
BRAZOS R.A.
WENDY LAGRONE 2559567 (BUS)
553 3016 (GT)
BOB HILL (HYDROLOGIST)

TxDOT Record of Maintenance: ________

TxDOT Rock Mass Field Description

Code Av-3
Page 3 of 4

Scanline Descriptions

Horizontal Scanline Number: 1

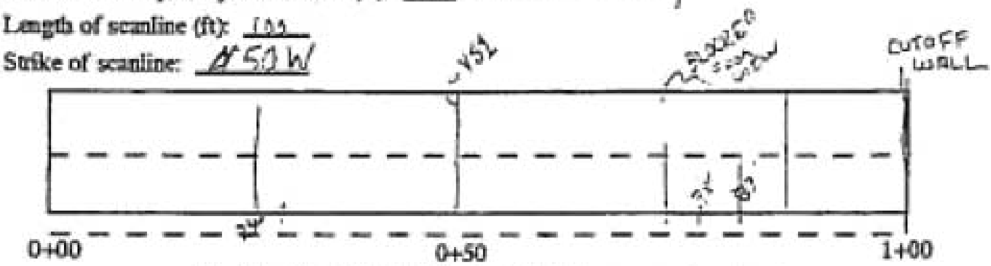
Horizontal Location (key into profile sketch and elevation sketch): ______

Height above base of cut (ft): 0

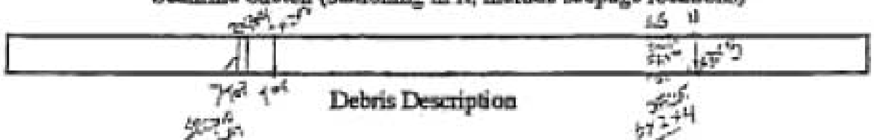
If within one layer, layer thickness (ft): 5' (BOTTOM LAYER)

Length of scanline (ft): 100

Strike of scanline: N 50 W



Scanline Sketch (stationing in ft, include seepage locations)



Debris Description

Scanline Information:

Obsn	Station	Set	Strike (w/r to exposure)				Dip (w/r to exposure)				Persist	Cond'n	Remarks
			±20°	20-45°	45-90°	R/L	±20°	20-45°	45-90°	R/L			
1	[illegible]				X		X			R	BED	TIGHT	POSSIBLE BLAST
2	[illegible]				X		X			K	"	"	"
3	[illegible]				X		X			R	"	SAME CLAY	"
4													
5													
6													

Description Keys:

Strike or Dip: R = into slope to the right
L = into the slope to the left

Condition: Closed — rough, undulating, planar, slickensided
Filled — sandy, clayey, gouge, filling thickness

Persistence — exposed length (ft), continuous through outcrop, bed-confined, termination index:
T(
S
R (in
ENDS IN BED
TERM. IN BED
MAJOR THRU FORM

Debris: Estimated block size (ft), Joint or blast formation, Differential Weathering
"UNIT

TxDOT Rock Mass Field Description

Code Av-3
Page 4 of 4

Scanline Descriptions

Vertical Scanline Number: 1

Scanline Location (key into profile sketch and elevation sketch): ________

Height of scanline (ft): _____

Length of scanline: ________

Scanline Sketch

3' topsoil/rock
2' caprock solid massive
5' intact vuggy possibly soft
6' 2" to 1' beds resistant
solutioned
12' massive
2' soft marly
4½' 6" layers
2 marly
5' massive

Scanline Information:

Obsn	Station	Set	Strike (w/r to exposure)				Dip (w/r to exposure)				Persist	Cond'n	Remarks
			±20°	20-45°	45-90°	R/L	±20°	20-45°	45-90°	R/L			
1													
2													
3													
4													
5													
6													

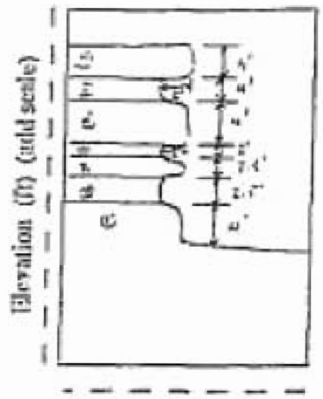
Fracture Frequency (disc/ft): ______

Estimated RQD: 25-35 solutioned
50-65 Non Solutioned

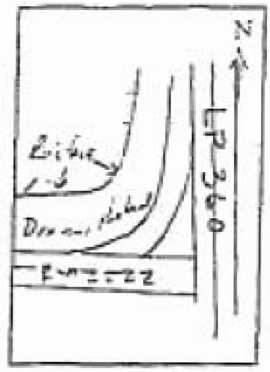
TxDOT Rock Mass Field Description

Code Av-2

Page 1 of 4



Profile Sketch



Plan/Map Sketch

Field Crew: MB, BMT

Date: 3-5-

Location: RM 2222 + LP 360

TxDOT District: 14 (Travis)

Geologic Formation: Glen Rose Formation

General Exposure Description

Dimensions and Orientation

Total height (ft) 15'

Lateral Extent (ft): 150'

Benches: number of levels: 0 height (ft): ______ width (ft) ______

Face orientation: strike/dip S50E / 585

Catchment Description: Concrete + next drainage channel

Support Installed: None

Method of Excavation (if blasted, describe blast effects) Presplit blasting 1/2 inch @ 3' centers possible sub parallel

Age of Exposure 7 years

Vegetation Effects None

Elevation (ft) (add scale)

Elevation Sketch of Exposure (ft) (add scale)

TxDOT Rock Mass Field Description

Code Av-2

Scanline Descriptions

Horizontal Scanline Number: 1

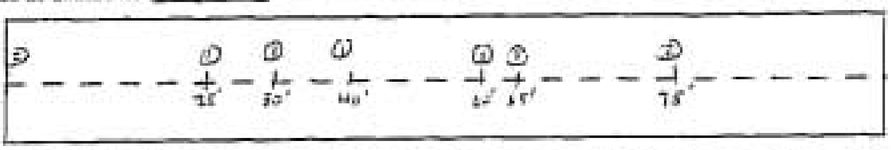
Horizontal Location (key into profile sketch and elevation sketch): ______

Height above base of cut (ft): 4'

If within one layer, layer thickness (ft): ?'

Length of scanline (ft): 108'

Strike of scanline: S55°



0+00 0+50 1+00

Scanline Sketch (stationing in ft, include seepage locations)

Block sizes 5'x3'x3' [illegible]

Debris Description

Scanline Information:

Obs^n	Station	Set	Strike (w/r to exposure)				Dip (w/r to exposure)				Persist	Cond'n	Remarks
			≤20°	20-45°	45-90°	R/L	≤20°	20-45°	45-90°	R/L			
1		1			✓	|			✓	⊥	bed confined	closed [illegible]	
2.		2			✓	|							[illegible]
3													
4													
5													
6													

Description Keys:

Strike or Dip: R = into slope to the right
L = into the slope to the left

Condition: Closed — rough, undulating, planar, slickensided
Filled — sandy, clayey, gouge, filling thickness

Persistence: exposed length (ft), continuous through outcrop, bed-confined, termination index: T, S, R

Debris: Estimated block size (ft), Joint or blast formation, Differential Weathering

TxDOT Rock Mass Field Description

Code Av-2
Page 3 of 4

Scanline Descriptions

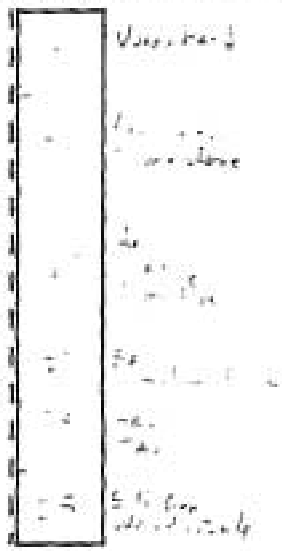
Vertical Scanline Number: 1

Scanline Location (key into profile sketch and elevation sketch): ________

Height of scanline (ft): 9'

Length of scanline: 12'

Elevation (ft) (add scale)



Scanline Sketch

Scanline Information:

Obsn	Station	Set	Strike (w/r to exposure)				Dip (w/r to exposure)				Persist	Cond'n	Remarks
			±20°	20-45°	45-90°	R/L	±20°	20-45°	45-90°	R/L			
1													
2													
3													
4													
5													
6													

Fracture Frequency (disc/ft): ______

Estimated RQD: 62-75

TxDOT Rock Mass Field Description

Code AU-2

Page 4 of 4

Summary Geologic Description

Bedding Description: Strike/dip: ________

Layer	Thickness	Geologic Formation	Physical Properties	Remarks	Samples Taken
1	5'	Glen Rose (GR)	Hard, [illegible]		None
2		GR	Silty, gray, weathered		
3		GR	Massive, gray, hard		
4		GR	[illegible] weathered		
5		GR	thick bed[illegible] sandy [illegible]		
6		GR	Arg[illegible]		
7		GR	[illegible]		

Joint Description Summary

Joint Set	Strike	Dip	Condition	Persistence
			All joints are bed	
			confined.	

Major Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks

Differential Weathering: Yes, Layers 2, 4 and 6

Active Erosion: None

Geotechnical Data (core available, site investigation report?): ________

Form of Slope Degradation: differential weathering resulting in block fall

TxDOT Contact: Wes [illegible]

TxDOT Record of Maintenance: None

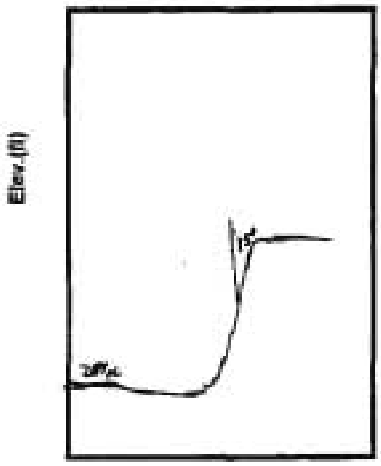
Date: 5/14/05
Page 1 of 4
Code 281-2

TxDOT Rock Mass Field Description

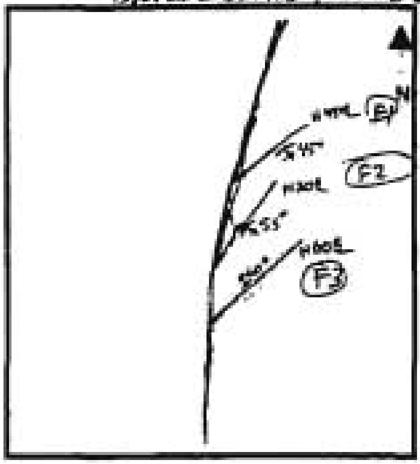
Glen Rose Formation

Location: U.S. 281 N. Bound South of S.H. 46 Across From Entrance to Bulverde Estates, Comal Co.

TxDOT District: San Antonio



Profile Sketch



Plan Sketch

General Exposure Description

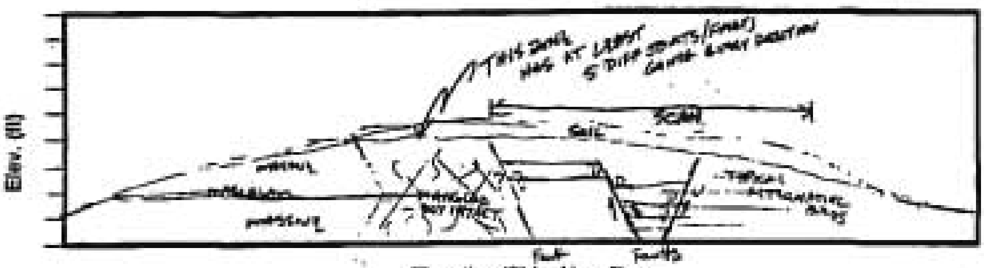
Dimensions and Orientation:

Total Height (ft): 20'-25'
Lateral Extent (ft): 520'
~~Benches: Height Width~~
L1
L2
L3
Face Orientation: Strike/dip: 15° (75°)
Catchment Description: Set back 20' from
Artificial Support: None

Method of Excavation (incl. effects): Blast

Age of Exposure:

Vegetation Effects: None



Elevation (ft) looking East

TxDOT Rock Mass Field Description

Glen Rose Formation

Summary of Engineering Geologic Data

OUT OF FACE
INTO FACE

Joint Description Summary

Set #	Strike	Dip	Roughness	Separation/ Filling	Persistence	Weathering	Remarks
1	N 45 W	90°	R/P	TIT1	P	II	
2	N 30 E	50° SE	R/S/SS	TIT2	P	II	
3	N 30 E	45° NW	R/P	TIT2	P	II/IIb	
4							

Other Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks	
FAULT 1	N 60° E	60° NW	S/U/II	P	6" OFFSET	← INTO FACE
FAULT 2	N 20° E	55° SE	R/[illegible] (M-H)	I , P	1-1.5' OFFSET	← OUT OF FACE
FAULT 3	N 45° E	45° SE	S/[illegible] w/ [illegible], II, P		[illegible] OFFSET	" " "

Occasional Random Joints? YES

Bedding Description: SOUTH OF FAULT ZONE TYPICAL ALTERNATING HARD/SOFT BEDS
NORTH OF FAULT ZONE IS [illegible] [illegible] NODULAR [illegible] w/ MARLY LAY[ER]
AT MID HEIGHT

Weathering/Erosion: THIN MARL BEDS HAVE ERODED 1-2'

Form of Slope Failure/Degradation: BLOCK, LARGE @ JT.' FAULT INTERSECTIONS,
MINOR RAVELING

Debris: 1-3' BLOCKS AT HIGHLY JOINTED AREAS

Maintenance Record:

Available Geotechnical Data:

TxDOT Rock Mass Field Description

Glen Rose Formation

Scanline Descriptions

Horizontal Scanline Number: 1
Horizontal Location (locate on sketch): START @ F3 GO SOUTH (244')
Height above base of cut (ft): 4'
If w/in one layer, layer thickness: ______
Length of scanline (ft): 244'
Strike of scanline (if different from face): ______

0+00 | 0+50 | 1+00

Scanline Sketch (include seepage locations)

N PACES S

Debris Description

J1 FLAT N 40W
J3 IN N 3?R
J2 OUT N 30E

obs #	Sta. PACE/FT	Set	Strike w/r to exposure +/-20	20-45	45-90	R/L	Dip w/r to exposure +/-20	20-45	45-90	R/L	Persist.	Condition
1	0 / 0	F3		X		L			X	L	P	SMOOTH / 2"-3" FACIAL / II-III / DRY
2	0 / 0	J1			X	R	0			N/A	P	R/P/TITE/II/DRY
3	5 / 22	J2		X		L			X	R	NP(BC)	R/U/TITE/II/DRY
4	12 / 52	F2		X		L			X	L	P	S/P/TITE to 1/4"-1/2"/II/DRY
5	12 / 52	J3		X		L			X	R	P	R/U/TITE/II/DRY
6	16 / 70	F1			X	L		X		R	P	S/U/TITE/III/DRY
7	18 / 78	J1			X	R	X			N/A	P	R/P/T/II/DRY
8	19 / 83	J1			X	R	X			N/A	P	R/P/TITE/II/DRY
9	21 / 91	Random			X	R		X		R	P	R/U/TITE/II/DRY
10	25 / 109	J1			X	R	X			N/A	P	R/P/TITE/II/DRY
11	26 / 113	J1			X	R	X			N/A	P	" " " "
12	27 / 122	J1			X	R	X			N/A	P	" " " "
13	35 / 152	J1			X	R	X			N/A	P	" " " "
14	42 / 183	J2		X		L		X		R	P	VR/U/TITE/II/DRY
15	42 / 183	J3		X		L			X	R	P	R/U/1/2" OPENING/III/DRY
16	45 / 196	J2		X		L		X		R	P	VR/U/TITE/II/DRY
17	45 / 196	J1			X	R	X			N/A	P	R/P/TITE/II/DRY
18	47 / 204	J1			X	R	X			N/A	P	" " " " "
19	50 / 218	J3		X		L			X	R	P	S/U/TITE/II/DRY
20	52 / 226	J3		X		L			X	R	P	" " " " "
	52 / 226	J1			X	R	X			N/A	P	R/P/TITE/DRY
	56 / 244	J2		X		L		X		R	P	S/U/TITE/II/DRY
	56 / 244	J3		X		L			X	R	P	S/U/TITE/II/DRY

Set	Apparent spacing (ft/scan length)	True Spacing (ft/scan length)
1	24 ft	15 ft
2	81 ft	41 ft
3	41 ft	31 ft
4		
5		

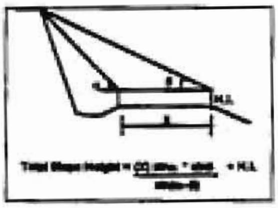
Page 4 of 4
Code 2/P-2

TxDOT Rock Mass Field Description
Glen Rose Formation

Scanline Descriptions

Vertical Scanline Number: ________
Scanline Location (show on sketch): ____________________
Height of Scanline (ft): ________
Lrength of Scanline(ft): ________

P-22
P-23
P-24
P-1 for P-7



Scanline Sketch

Fracture frequency: ________
Est. RQD: ________

Scanline Information:

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Cond'n
			+/-20	20-45	45-90	R/L	+/-20	20-45	45-90	R/L		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												

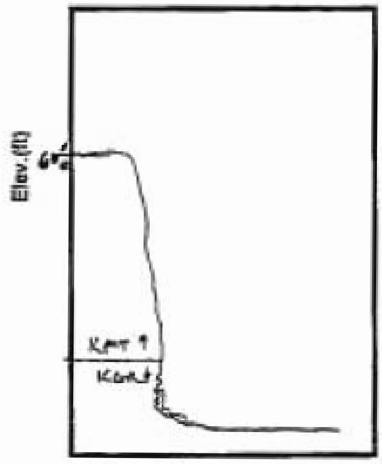
Date: 6/13/95
Page 1 of 4
Code 337-1

TxDOT Rock Mass Field Description

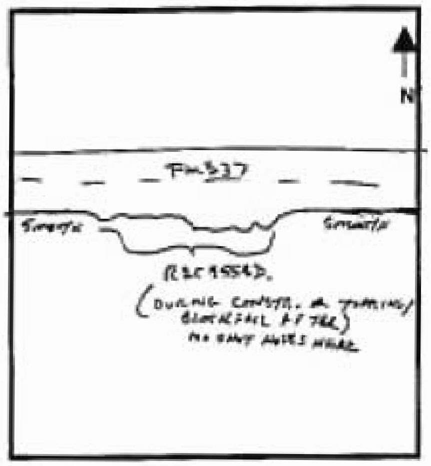
Formation: Kpt / Kgr

Location: FM 337 JUST EAST OF MILL CREEK ROAD
RM 442

TxDOT District: SAN ANTONIO



Profile Sketch



Plan Sketch

General Exposure Description

Dimensions and Orientation:

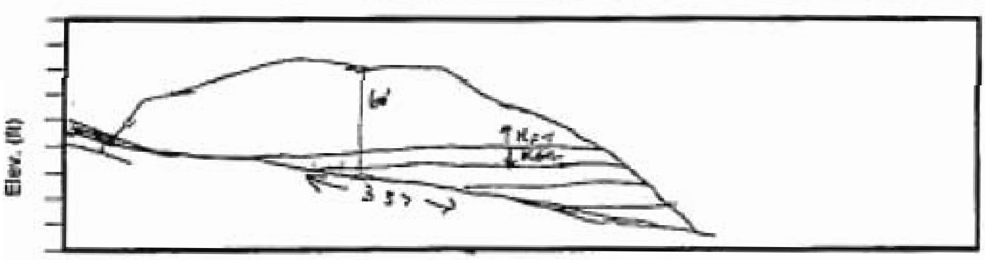
Total Height (ft): 60'
Lateral Extent (ft): .15 MI × .35 = 650'
~~Benches:~~ ~~Height~~ Width
L1
L2
L3

Face Orientation: Strike/dip: DUE WEST / 75°
Catchment Description: NONE, GOES UP TO PVMT
Artificial Support: NONE

Method of Excavation (incl. effects): BLAST

Age of Exposure: ______

Vegetation Effects: OCC. SEP. WEED IN GCW ROSE



Elevation (ft) looking SOUTH

TxDOT Rock Mass Field Description

Summary of Engineering Geologic Data

Joint Description Summary

Set #	Strike	Dip	Roughness	Separation/ Filling	Persistence	Weathering	Remarks
1	N 65°E	75°	V. ROUGH/UND	UP TO 1 FT,	THROUGH GOING	II	FILLED IN SOME PLACES W/ BRECCIA
				TIR @ TOP OF SLOPE			
2	N 40°W	90°	V. ROUGH/UND	TIT TO 3"	THROUGH GOING	II	SILT → GRAVEL WHERE OPEN

Other Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks

Occasional Random Joints? YES VERTICAL BC FRACTURES / JOINTS IN Kg

Bedding Description: MASSIVE, NODULAR, VUGGY IN Ket, 2'-4' ALTERNATING BEDS IN Kgr

Weathering/Erosion: SEVERE EROSION / SLUMPING IN Kgr. DISCOLORATION IN Ket. SOME FRESH TAN SURFACES INDICATE SPORADIC RAVELLING / MINOR ROCKFALL (2'-3' BLOCKS)

Form of Slope Failure/Degradation: ~~[illegible]~~ MINOR RAVELLING IN Ket, SEVERE RAVELLING, BLOCK FALL IN Kgr. POTENTIAL FOR LARGE TOPPLING IN Ket @ ST 337 1 MASS

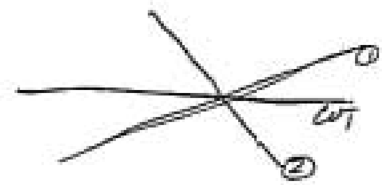
Debris: GRAVEL TO 2' BOULDERS

Maintenance Record:

Available Geotechnical Data:

TxDOT Rock Mass Field Description

Scanline Descriptions



Horizontal Scanline Number: 1
Horizontal Location (locate on sketch): ____________
Height above base of cut (ft): 15'
If w/in one layer, layer thickness: ____________
Length of scanline (ft): Entire cut ≤ 50'
Strike of scanline (if different from face): ____________

0+00 0+50 1+00
Scanline Sketch (include seepage locations)

Debris Description

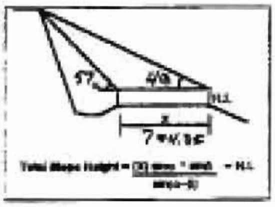
obs #	Sta.	Set	Strike wrt to exposure				Dip wrt to exposure				Persist.	Condition
			+/-20	20-45	45-60	R/L	+/-20	20-45	45-60	R/L		
1		1		X		L	X			R	P	VR/[illegible] 1" [illegible]/[illegible]/II [illegible]
2		2		X		R	X			[illegible]	P	VR/[illegible]/[illegible] 4"/[illegible]/II
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												

Set	Apparent spacing (#/scan length)	True Spacing (#/scan length)
1	72"	41"
2	130	113"
3		
4		
5		

TxDOT Rock Mass Field Description

Scanline Descriptions

Vertical Scanline Number: ______
Scanline Location (show on sketch): ______
Height of Scanline (ft): ______
Length of Scanline(ft): ______



Scanline Sketch

VSST RAD
K_{FT} = 80-100
K_{tr} = 40-60

Photo Listing

No.	Description
17	
18	
19	
20	
21	

Samples Taken: None

Scanline Information:

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Cond'n
			+/-20	20-45	45-60	R/L	+/-20	20-45	45-60	R/L		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

Date: 6/3/05
Page 1 of 4
Code 2-10-6

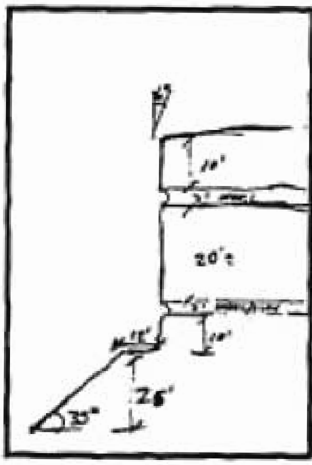
TxDOT Rock Mass Field Description

Formation: FT. TERRETT / EDWARDS

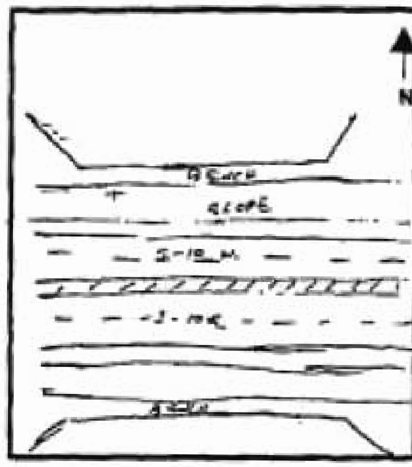
Location: I-10 1 MILE W. OF S.H.16

TxDOT District: SAN ANTONIO

Elev. (ft)



Profile Sketch



Plan Sketch

General Exposure Description

Dimensions and Orientation:

Total Height (ft): 70'

Lateral Extent (ft): 80 @ 1.35 = 350'

Benches: Height Width

L1 ______

L2 ______

L3 ______

Face Orientation: Strike/dip: DUE WEST / 84°

Catchment Description: SET BACK 20' FROM EOP

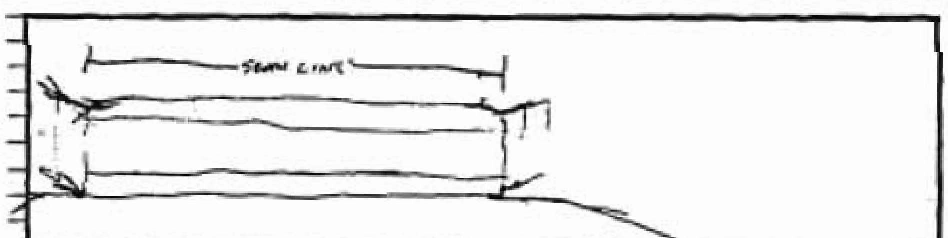
Artificial Support: NONE

Method of Excavation (incl. effects): PRE SPLIT ; MECHANICAL (LOWER SLOPED PORTION

Age of Exposure: ______

Vegetation Effects: DEPRESSION WATER ON SLOPE ; BENCH

Elev. (ft)



Elevation (ft) looking N

TxDOT Rock Mass Field Description

Summary of Engineering Geologic Data

Joint Description Summary

Set #	Strike	Dip	Roughness	Separation/ Filling	Persistence	Weathering	Remarks
1	N65°W	40°	V. ROUGH	T.T.	P	II	UNDULATING TO PLANAR
2	N50°E	60°NW	V. ROUGH	TITE TO 5mm	P	II	UNDULATING
3	N40°E	60°SE	ROUGH	TITE TO 2mm	P	II	UNDULATING
4							

Other Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks

Occasional Random Joints? ______________________

Bedding Description: MASSIVE BEDS EXCEPT FOR THE TWO MARL BEDS AND THIN 2'-4' BEDS ON LOWER SLOPE

Weathering/Erosion: DISCOLORATION OF FACE, EROSION OF MARL BEDS LEAVES ONE FOOT OF RETREAT FROM FACE

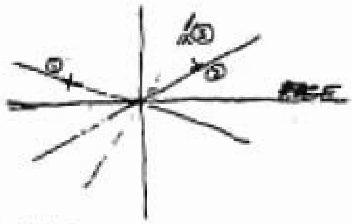
Form of Slope Failure/Degradation: MINOR SPALLING/RAVELLING

Debris: CLAY TO 8"-10" BOULDER SIZE AT TOE OF VERTICAL CUT; NONE AT BOTTOM OF SLOPED PORTION

Maintenance Record: ______________________

Available Geotechnical Data: ______________________

TxDOT Rock Mass Field Description



Scanline Descriptions

Horizontal Scanline Number: 1
Horizontal Location (locate on sketch): ENTIRE VERT. CUT
Height above base of cut (ft): 6'
If w/in one layer, layer thickness:
Length of scanline (ft): 80 x 4.38 = 350' EAST TO WEST
Strike of scanline (if different from face): SAME

0+00 0+50 1+00

Scanline Sketch (include seepage locations)

Debris Description

obs #	Sta. mo/ft	Set	Strike w/r to exposure 0-20	20-45	45-90	R/L	Dip w/r to exposure 0-20	20-45	45-90	R/L	Persist.	Condition
1	0/0	3			X	L		X		R	[illegible]	TITE to 5mm/R, U/D/II no FILLING
2	2/	1			X	R	X			N/A	" "	TITE/R U/II/no FILLING
3	6/	1			X	R	X			N/A	" "	5-10mm/R, U/III/ [illegible] FILLING
4	11/	1			X	R	X			N/A	" "	TITE/R, U/II/ NO FILLING
5	13/	3			X	L		X		R	" "	TITE to 3mm/R, U/II/DRY/NO FILLING
6	16/	3			X	L		X		R	" "	" " " " " "
7	18/	1			X	R	X			N/A	" "	TITE/R, U/II/DRY/NO FILLING
8	27/	1			X	L	X			N/A	" "	" " " " "
9	30/	1			X	L	X			N/A	" "	" " " " "
10	34/9	3			X	L		X		R	" "	TITE/R, U/IB/DRY/NO FILL
11	36/	1			X	R	X			N/A	" "	TITE/R, U/IA/DRY/NO FILL
12	39/	3			X	L		X		R	" "	TITE to 3mm/R, U/II/DRY/NO FILL
13	43/	1			X	R	X			N/A	" "	T/R, U/IB/DRY/NO FILL
14	48/	1			X	R	X			N/A	" "	" " /IA/DRY/NO FILL
15	52/	2		X	"	L		X		L	" "	T/R, U/II/DRY/NO FILL
16	52/	1			X	R	X			N/A	" "	T/R, U/IA/DRY, NO FILL
17	60/	2		X		L		X		L	" "	T/R, U/II/D/NO FILL
18	61/	1			X	R	X			N/A	" "	T/R, U/I/D/NO FILL
19	63/	1			X	R	X			N/A	" "	" " " " "
20	88/	1			X	R	X			N/A	" "	5mm/R, U/II/DAMP [illegible] FILL
21												
22												

Set	Apparent spacing (ft/scan length)	True Spacing (ft/scan length)
1	27'	11'
2	175'	112'
3	70'	54'
4		
5		

TxDOT Rock Mass Field Description

Scanline Descriptions

Vertical Scanline Number: ________
Scanline Location (show on sketch): ________
Height of Scanline (ft): ________
Length of Scanline(ft): ________

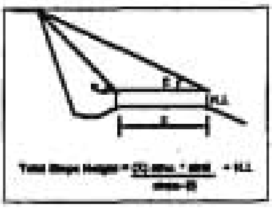


Photo Listing

No.	Description
8	PANORAMIC LKG EAST
9	" " "
10	PANORAMIC LKG W
11	" " NNW

Scanline Sketch

EST. RQD
80-90

Samples Taken: NONE

Scanline Information:

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Cond'n
			+/-20	20-45	45-90	R.L.	+/-20	20-45	45-90	R.L.		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

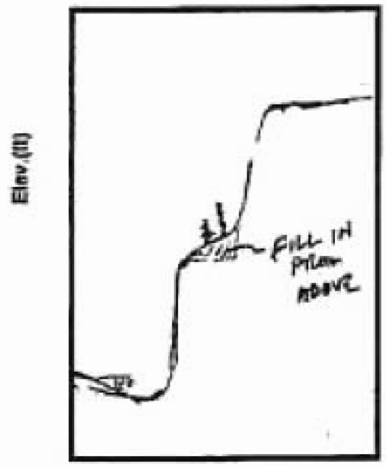
Date: ____
Page 1 of 4
Code 360-1

TxDOT Rock Mass Field Description

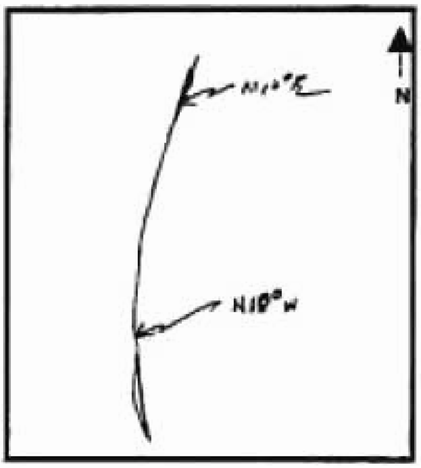
Glen Rose Formation

Location: 360 just N. of Bull Creek Rd.
West side of road

TxDOT District: AUSTIN



Profile Sketch



Plan Sketch

General Exposure Description

Photos 18-21

Dimensions and Orientation:

Total Height (ft): 75'
Lateral Extent (ft): 1000'
Benches: 1 Height Width
L1 35' 10-12' Bench filled w/debris & [illegible] weed
L2 [illegible] 30° dip Bench totally ineffective because it is so full of fall off it is sloped [illegible]
L3 ____

Face Orientation: Strike/dip: N10°E → N10°W [illegible]
Catchment Description: Ditch: 15' from top 15' slope to cut
Artificial Support: N/A (Bench)

Method of Excavation (incl. effects): Blast - pre split

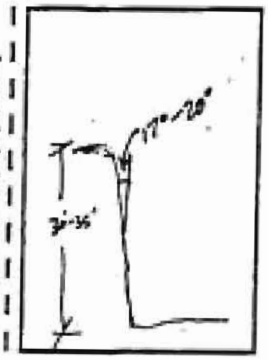
Age of Exposure: 15yrs
Vegetation Effects: [illegible] weed on bench

Elev. (ft)

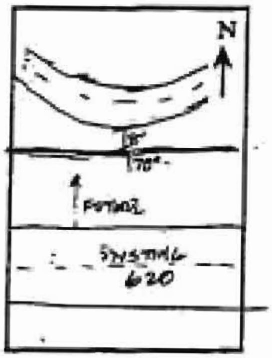
Elevation (ft) looking ___

TxDOT Rock Mass Field Description

Code 620-1
Page 1 of 3



Profile Sketch



Plan/Map Sketch

Field Crew: BM, MG, CJY

Date: 3/5/95

Location: 620

TxDOT District: AUSTIN

Geologic Formation: GLEN ROSE

2 DAYS AFTER RAIN, SEVERAL JOINTS WET

General Exposure Description

Dimensions and Orientation

Total height (ft) (30'-35' UPPER SLOPE TOWARD DAM) - (20' LOWER SLOPE)

Lateral Extent (ft): (410' L) (520' U)

Benches: number of levels: 1 height (ft): ____ width (ft) ____

Face orientation: strike/dip (N90°W DIP WEST LOWER) (N80°E UPPER)

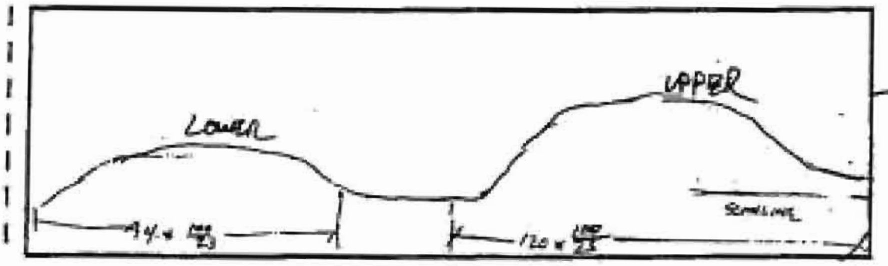
Catchment Description: N/A

Support Installed: N/A

Method of Excavation (if blasted, describe blast effects) RIP / HOE RAM

Age of Exposure FRESH (MARCH 95)

Vegetation Effects N/A



Elevation Sketch of Exposure (ft) (add scale)

PACE 23 STRIDES / 100'

HIGH WALL 120 STRIDES

TxDOT Rock Mass Field Description

Code 620 - 1

Page 2 of 3

Summary Geologic Description

Bedding Description: Strike/dip: ________

Layer	Thickness	Geologic Formation	Physical Properties	Remarks	Samples Taken

Joint Description Summary

Joint Set	Strike	Dip	Condition	Persistence
1	N40°E	73°	~~[illegible]~~ PLANAR	BC, 8'
2	N40E	55°	VARIES (P, U, R)	[illegible] THROUGH GOUGE

Major Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks

Differential Weathering: YES

Active Erosion: N/A

Geotechnical Data (core available, site investigation report?): ?

Form of Slope Degradation: N/A

TxDOT Contact: ________

TxDOT Record of Maintenance: ________

TxDOT Rock Mass Field Description

Code G20-1
Page 1 of 3

Scanline Descriptions

Horizontal Scanline Number: 1

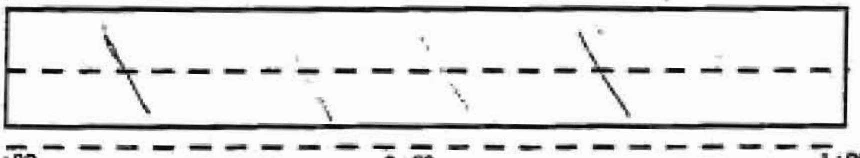
Horizontal Location (key into profile sketch and elevation sketch): ______

Height above base of cut (ft): 5-6'

If within one layer, layer thickness (ft): 2 LAYERS (10'±)

Length of scanline (ft): 100

Strike of scanline: [illegible] AS SLOPE



0+00 0+50 1+00

Scanline Sketch (stationing in ft, include seepage locations)

Debris Description

Scanline Information:

SPACING = 6.67'

Obs#	Station	Set	Strike (w/r to exposure)				Dip (w/r to exposure)				Persist	Cond'n	Remarks
			≤20°	20-45°	45-90°	R/L	≤20°	20-45°	45-90°	R/L			
1		1			X	X	X				15/100'	[illegible]	
2		2									9/100' [illegible]	[illegible]	[illegible]
3												[illegible]	
4													
5													
6													

Description Keys:

Strike or Dip: R = into slope to the right
L = into the slope to the left

Condition: Closed: rough, undulating, planar, slickensided
Filled: sandy, clayey, gouge, filling thickness

Persistence: exposed length (ft), continuous through outcrop, bed-confined, termination index: T, S, R

Debris: Estimated block size (ft), Joint or blast formation, Differential Weathering

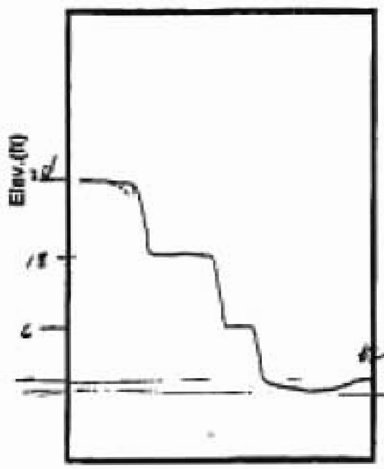
Date: 3/10
Page 1 of 2
Code 620-2

TxDOT Rock Mass Field Description

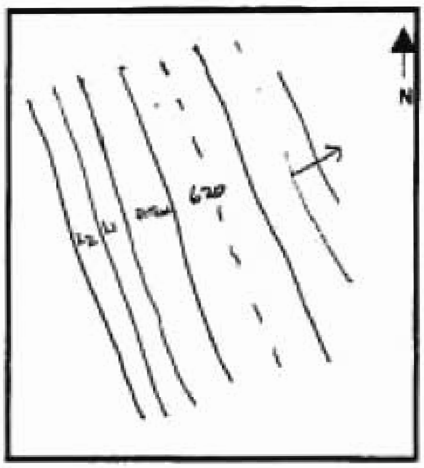
Glen Rose Formation

Location: RR 620 NEAR CAUSEWAY

TxDOT District: AUSTIN



Profile Sketch



Plan Sketch

General Exposure Description

Dimensions and Orientation:

Total Height (ft): 30'
Lateral Extent (ft): 360'
Benches: 2 Height Width
L1 6' 3'–6'
L2 12' 8'–10'
L3 10–12'

Face Orientation: Strike/dip: N 25° W, 70° to 72°
Catchment Description: 20' WIDE DITCH, SHALLOW DEPRESSION IN MIDDLE
Artificial Support: BENCHING

Method of Excavation (incl. effects): MECHANICAL

Age of Exposure: ______

Vegetation Effects: NONE

Elevation (ft) looking SW

TxDOT Rock Mass Field Description
Glen Rose Formation

Summary of Engineering Geologic Data

Joint Description Summary NO THROUGH-GOING JOINTS OR EVEN BENCH CONFINED.

Set #	Strike	Dip	Roughness	Separation/ Filling	Persistence	Weathering	Remarks
	NUMEROUS BED CONFINED DISCS						

Other Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks

Bedding Description: 2" TO 2'

Weathering: ALMOST ENTIRE CUT IS TAN ALS, LMS. ONLY BOTTOM 3' ARE UNWEATHERED GRAY.

Active Erosion: OCCASIONAL THIN MARLY SEAMS ARE BEHIND THE SURROUNDING ROCK

Available Geotechnical Data:

Form of Slope Failure/Degradation: MINOR RAVELING/SMALL BLOCKS

Debris: GRAVEL TO 8"-12" LS PIECES

Maintenance Record:

Description Key:

Roughness		Persistence	Water (ISRM Romana)		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TxDOT Rock Mass Field Description

Glen Rose Formation

Page 3 of 3
Code 6E-2

Scanline Descriptions

Horizontal Scanline Number: 1
Horizontal Location (locate on sketch): ____________
Height above base of cut (ft): 18'
If w/in one layer, layer thickness: 2'
Length of scanline (ft): ~~[illegible]~~ 77'
Strike of scanline (if different from face): SAME

0+00 0+50 1+00

Scanline Sketch (include seepage locations)

GRAVEL TO 1" SIZE LCS, WDLS FRAGS

Debris Description

obs #	Sta. (FEET)	Set	Strike w/r to exposure +/-20	20-45	45-90	R/L	Dip w/r to exposure +/-20	20-45	45-90	R/L	Persist.	Cond'n	Remarks
1	0+06				X	R	X			–	NM/BC	1-3mm open	no FILL UND/V. ROUGH
2	0+16			X		R		X			NM/BC	TIGHT	UND/ROUGH
3	0+23				X	R		X			THRU BED	TIGHT	UND/V. ROUGH
4	0+24				X	R		X			NM/BC	TIGHT	UND/V. ROUGH
5	0+32				X	R	X				NM/BC	TIGHT	UND/ROUGH
6	0+34				X	R		X			NM/BC	TIGHT	UND/V. ROUGH
7	0+49			X		R		X			THRU 3 BEDS	1/2" w/[illegible]	[illegible] UND/V. ROUGH
8	0+56				X	R		X			2 BEDS(4')	3mm CL[illegible]	/ UND, V. ROUGH
9	0+61		X			R		X			NM/BC	2mm CL	/ UND SMOOTH
10	0+67				X	R		X			2 BEDS	5mm open + CL/BC	/ UND. V. ROUGH
11	0+75				⊥	NA		X			NM/BC	2mm CL/BC	/ UND V. ROUGH
12	0+77			X		L		X			NM/BC	TIGHT	UND/ROUGH
13													
14													
15													
16													
17													
18													
19													
20													

Set	Apparent spacing (#/scan length)	True Spacing (#/scan length)
1		
2		
3		
4		
5		

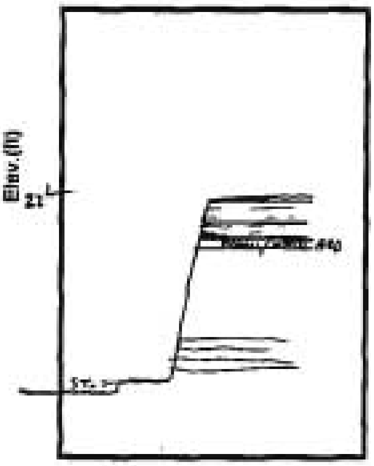
Date: 5/4/95
Page 1 of __
Code 2244-1

TxDOT Rock Mass Field Description

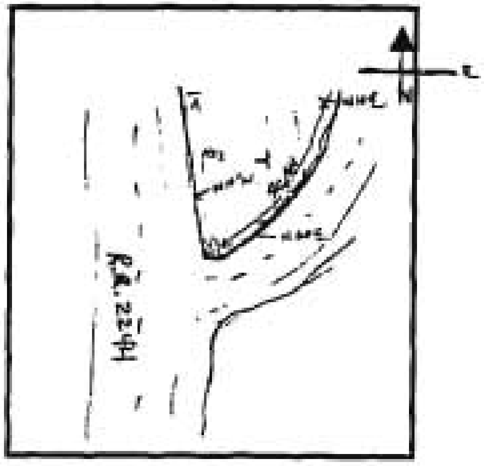
Glen Rose Formation

Location: R.R. 2244 @ ADDIE ROY RD

TxDOT District: AUSTIN



Profile Sketch



Plan Sketch

General Exposure Description

Dimensions and Orientation:

N 35 E around to
N 60°E
N 10°W

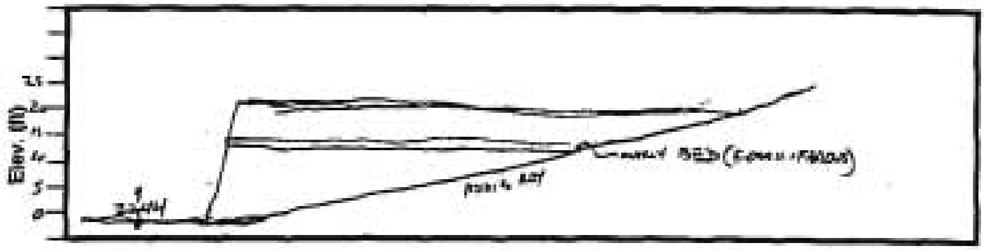
Total Height (ft): 22'
Lateral Extent (ft): 77± 1st ≅ 370'
Benches: Height Width
L1
L2
L3

Face Orientation: Strike/dip: N35°E – N60°E – N10°W 12° FROM VERTICAL
Catchment Description: BASICALLY FLAT AREA 8-12' WIDE
Artificial Support: NONE

Method of Excavation (incl. effects): BLAST - PRE SPLIT, SOME MINOR CRACKING AT SHOT HOLES

Age of Exposure: ______

Vegetation Effects: NONE



Elevation (ft) looking NW

Page ___ of ___
Code ________

TxDOT Rock Mass Field Description
Glen Rose Formation

Summary of Engineering Geologic Data

Joint Description Summary

Set #	Strike	Dip	Roughness	Separation/ Filling	Persistence	Weathering	Remarks
1	N 10°W	81° [illegible]	UR	[illegible] to 1" w/ [illegible]	P	III	

Other Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks

Occasional Random Joints? ~~[illegible]~~ YES ALONG 2244 SIDE - ONLY 2, CLOSE TO VERTICAL, TIGHT, ⊥ TO CUT

Bedding Description: 4 or 5 ~6"–1' thick beds @ bottom, then 12"–15" MASSIVE BED, THEN 1'–2' BEDS

Weathering/Erosion: NOT BAD AT ALL ~ 1 MARLY LAYER 5'-0" FROM TOP (1' THICK)

Form of Slope Failure/Degradation: BLOCK FALL ~ MOSTLY IN UPPER THINNER BEDS @ TOP OF SLOPE, SOME MINOR RAVELING

Debris: 1.5'–2' BLOCKS, SOME SMALL PEBBLE-COBBLE SIZE DEBRIS

Maintenance Record:

Available Geotechnical Data:

UPPER BEDS of ABOVE MARL LAYER HAVE BEEN DISPLACED TO THE SOUTH IN THE AREA TOWARD MAX CURVATURE OF THE CUT (P-12)

TxDOT Rock Mass Field Description

Glen Rose Formation

Page ___ of ___

Code ________

Scanline Descriptions

Horizontal Scanline Number: 1

Horizontal Location (locate on sketch): FROM 2244' TO NE UP [illegible] RD.

Height above base of cut (ft): [illegible] CUT

If w/in one layer, layer thickness: ________

Length of scanline (ft): 150'

Strike of scanline (if different from face):

FM 2244

Scanline Sketch (include seepage locations)

140+00

1'-3' BOULDERS

Debris Description

obs #	Sta.	Set	Strike w/r to exposure +/-20	20-45	45-90	R/L	Dip w/r to exposure +/-20	20-45	45-90	R/L	Persist.	Condition
1	0+00	1	X		X	L	X				P	UR, DRY, (TIT) OPEN 1"
2	24+00	1	X		X	L	X				P	U.S., DRY, TITE TO 1/4", (1a)
3	45+00	1	X		X	L	X				P	U.R., DRY, FILLED(1/4-1/2") [illegible]
4	47+00	1	X		X	L	X				P	U.R., DRY, TITE (1a)
5	64+00	1	X		X	L	X				P	U.R., TITE TO 1/4", 1a, DRY
6	124+00	1	X		X	L	X				P	U.R., TITE, 1a, DRY
7	126+00	1	X		X	L	X				P	" " " "
8	130+00	1	X		X	L	X				P	" " " "
9	138+00	1	X		X	L	X				P	" " " "
10	146+00	1	X		X	L	X				P	" " " "
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												

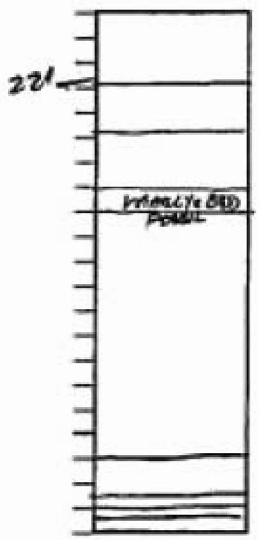
Set	Apparent spacing (ft/scan length)	True Spacing (ft/scan length)
1	15'	14'
2		
3		
4		
5		

TxDOT Rock Mass Field Description
Glen Rose Formation

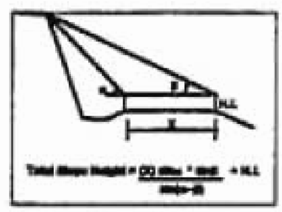
Scanline Descriptions

Vertical Scanline Number: 1
Scanline Location (show on sketch): ____________
Height of Scanline (ft): ________
Length of Scanline(ft): 5'

P-8
P-9
P-10
P-11 JOINT
P-12 DISPLACED BEDS
P-13 JOINTS, [illegible] LAYER
P-14 JT OF FOOT, LOOSE UPPER BLOCKS



Scanline Sketch



Fracture frequency: ________
Est. RQD: 60-75

Scanline Information:

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Cond'n
			+/-30	30-45	45-90	R/L	+/-30	30-45	45-90	R/L		
1	#+00											
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												

Date: 5/9/95
Page 1 of 4
Code 2244-2

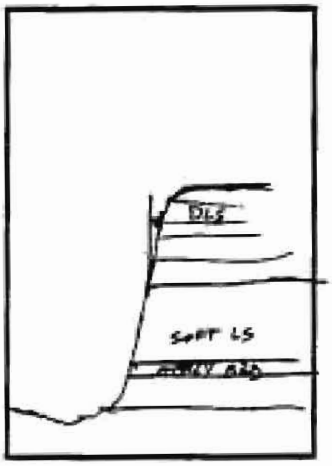
TxDOT Rock Mass Field Description

Glen Rose Formation

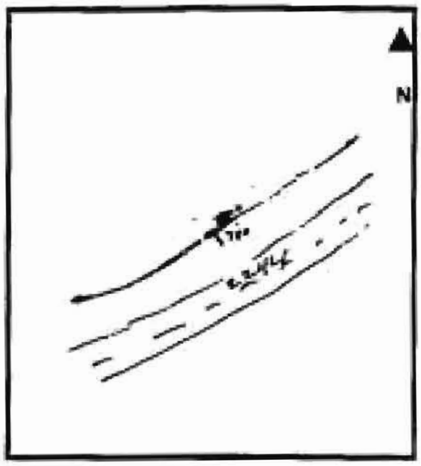
Location: FM 2244 @ CRYSTAL CREEK RD, IN AUSTIN

TxDOT District: AUSTIN

Elev. (ft)



Profile Sketch



Plan Sketch

General Exposure Description

MAJOR SEEPAGE

Dimensions and Orientation:

Total Height (ft): 10' MAX
Lateral Extent (ft): 550'
~~Benches:~~ ~~Height~~ ~~Width~~
~~L1~~
~~L2~~
~~L3~~

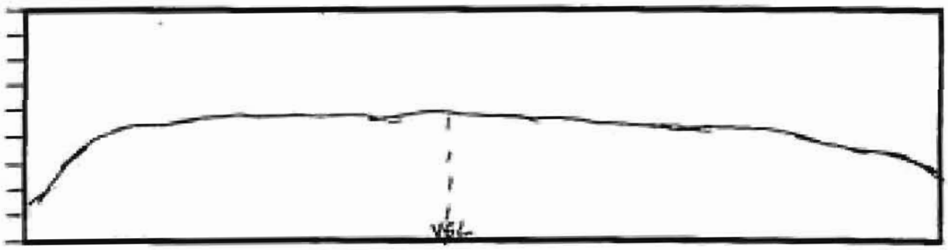
Face Orientation: Strike/dip: N70°E, 75° SE
Catchment Description: SHALLOW DITCH, 15' FROM EOP
Artificial Support: NONE

Method of Excavation (incl. effects): BLAST - ROUGH SURFACE

Age of Excavation:

Vegetation Effects: NONE

Elev. (ft)



Elevation (ft) looking NW

Page 2 of 4
Code 2244-2

TxDOT Rock Mass Field Description
Glen Rose Formation

Summary of Engineering Geologic Data

Joint Description Summary

Set #	Strike	Dip	Roughness	Separation/ Filling	Persistence	Weathering	Remarks

Other Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks

TO THICK SOFTER BED

Occasional Random Joints? N 65° W, N 35° E BED CONFINED, TITE BUT WET

Bedding Description: ALTERNATING HARD/SOFTER LAYERS 1.5'–4' BEDS

Weathering/Erosion: SOFT MARL LAYERS BEING ERODED
LOTS OF SEEPAGE FROM BEDDING PLANES, JOINTS

Form of Slope Failure/Degradation: SPALLING / RAVELLING OF SOFTER LS LAYER
ABOVE MARL BED CONCHOIDAL BREAKS

Debris: SOIL SIZE TO 2' BOULDER

Maintenance Record:

Available Geotechnical Data:

TxDOT Rock Mass Field Description
Glen Rose Formation

Page 3 of 4
Code 2244-2

Scanline Descriptions

Horizontal Scanline Number: ____
Horizontal Location (locate on sketch): ____________________
Height above base of cut (ft): ____
If w/in one layer, layer thickness: ______
Length of scanline (ft): ________
Strike of scanline (if different from face): ______________________________

0+00 0+50 1+00

Scanline Sketch (include seepage locations)

Debris Description

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Condition
			+/-20	20-45	45-90	R/L	+/-20	20-45	45-90	R/L		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												

Set	Apparent spacing (#/scan length)	True Spacing (#/scan length)
1		
2		
3		
4		
5		

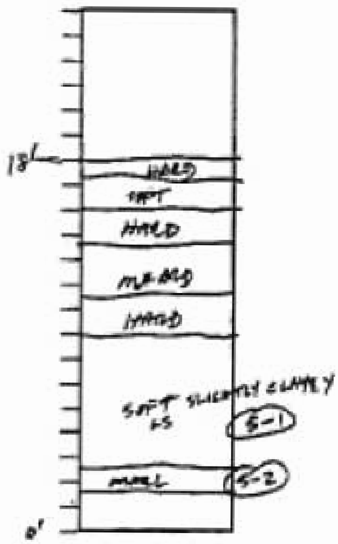
Page 4 of 4
Code 2249-2

TxDOT Rock Mass Field Description

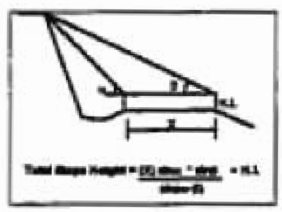
Glen Rose Formation

Scanline Descriptions

Vertical Scanline Number: 1
Scanline Location (show on sketch): MID LENGTH
Height of Scanline (ft): 16'
Length of Scanline(ft): 1"



Scanline Sketch



Fracture frequency: ________
Est. RQD: ________

Scanline Information:

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Cond'n
			+/-20	20-45	45-90	R/L	+/-20	20-45	45-90	R/L		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												

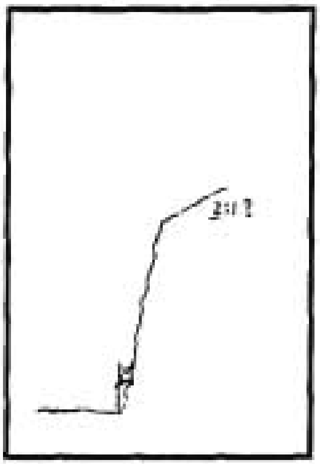
Date: 5/2/05
Page 1 of 58
Code SWP-1

TxDOT Rock Mass Field Description

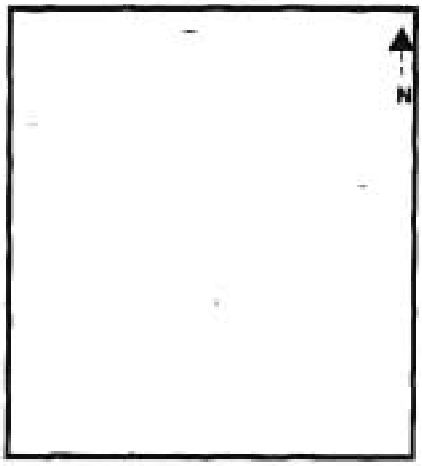
Glen Rose Formation

Location: SOUTHWEST PARKWAY NEAR TRAVIS COOK ROAD

TxDOT District: AUSTIN



Profile Sketch



Plan Sketch

General Exposure Description

Dimensions and Orientation:

Total Height (ft): 20' - 25'

Lateral Extent (ft): 210 PACES @ ... = ...

~~Benches~~: Height Width

L1 ______

L2 ______

L3 ______

Face Orientation: Strike/dip: DUE WEST / 12° LAYBACK (78° DIP)

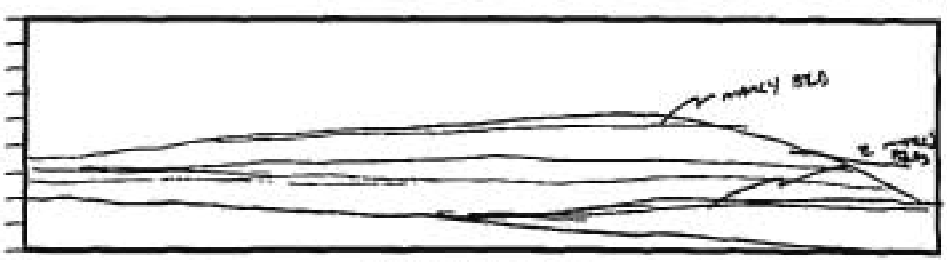
Catchment Description: DITCH (SHALLOW) 10' WIDE LINED W/ LS RIP-RAP

Artificial Support: NONE

Method of Excavation (incl. effects): BLASTING BUT W/ SOME MECHANICAL. MOST OR AT LEAST MANY OF THE SHOT HOLES ARE BEHIND THE FACE, NOT A SMOOTH FACE, SOME BLAST DAMAGE OBSERVED AT SHOT HOLES (P-1)

Age of Exposure: ______

Vegetation Effects: NONE



Elevation (ft) looking S

TxDOT Rock Mass Field Description
Glen Rose Formation

Summary of Engineering Geologic Data

Joint Description Summary

Set #	Strike	Dip	Roughness	Separation/ Filling	Persistence	Weathering	Remarks

Other Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks

Occasional Random Joints? BED CONFINED TO 2 OR 3 DIFFERENT HARD CRYSTALLINE BEDS (1'-2') VERTICAL JOINTS PRODUCING BOOK-LIKE APPEARANCE

Bedding Description: 1'-2' TO MASSIVE LS ONE THIN (6"-12") MARLY BED S-2 AND 2 THICK (2'-4') MARLY BEDS (S-1, S-3)

Weathering/Erosion: YOUNG CUT ∴ EROSION IS SLIGHT BUT NOTICEABLE ALONG MARLY LAYERS

Form of Slope Failure/Degradation: HARD CRYSTALLINE LAYERS ARE OCCASIONALLY FRACTURED, SMALL CHUNKS FALL FROM CANTILEVERED ~~[illegible]~~ SITUATIONS. SOME RAVELLING.

Debris: 2' TO 1.5' BOULDERS (OCCASIONAL)

Maintenance Record:

Available Geotechnical Data: SAMPLES TAKEN FOR SCALE (S-1) (F-8), (S-2), (S-3)

TxDOT Rock Mass Field Description
Glen Rose Formation

Page 3 of 4
Code 3W-1

Scanline Descriptions

Horizontal Scanline Number: ____
Horizontal Location (locate on sketch): ____________________
Height above base of cut (ft): ____
If w/in one layer, layer thickness: ________
Length of scanline (ft): ________
Strike of scanline (if different from face): ______________________________

0+00 0+50 1+00

Scanline Sketch (include seepage locations)

Debris Description

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Condition
			+/-30	30-45	45-60	R/L	+/-30	30-45	45-60	R/L		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												

Set	Apparent spacing (#/scan length)	True Spacing (#/scan length)
1		
2		
3		
4		
5		

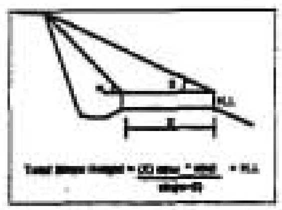
TxDOT Rock Mass Field Description
Glen Rose Formation

Scanline Descriptions

Vertical Scanline Number: ________
Scanline Location (show on sketch): ________
Height of Scanline (ft): ________
Lrength of Scanline(ft): ________

Scanline Sketch

PHOTOS
P-2 KARST [illegible]
P-3 CONCHOIDAL FRAC./CANTILEVER
P-4 WAVY BED; SLAKE (S-1)
P-5 LKG SE [illegible]
P-6 [illegible] RQD (S-2)
P-7 PANORAMIC LOOKING [illegible]
P-8 " " SOUTH



Fracture frequency: ________
Est. RQD: ________

Scanline Information:

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Cond'n
			+/-20	20-45	45-90	R/L	+/-20	20-45	45-90	R/L		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												

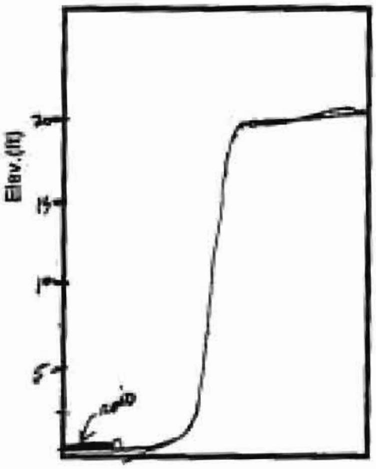
TxDOT Rock Mass Field Description

Glen Rose Formation

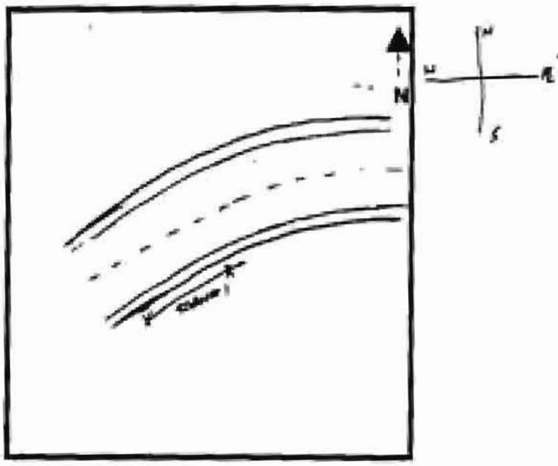
Date: 3/18/95
Page 1 of 4
Code 5RR1

Location: INTERSECTION OF STEINER RANCH RD & QUINLAN PARK RD. IN TRAVIS CO.

TxDOT District: AUSTIN



Profile Sketch



Plan Sketch

stride 21/100'

General Exposure Description

Photo's 9-14

Dimensions and Orientation:

Total Height (ft): max 30'

Lateral Extent (ft): 116 × 5/1 = 560'

~~Benches:~~ Height Width

L1 ______

L2 ______

L3 ______

Face Orientation: Strike/dip: N 91°E @ east end, N 85°E at mid section, N 70°E @ west end (dip = 82°)

Catchment Description: NONE; ONLY 6 ft between toe of slope & road (between RR Road)

Artificial Support: NONE

Method of Excavation (incl. effects): PRE-SPLIT: SHOT HOLES WERE OBSERVED

Age of Exposure: less than 5 yr

Vegetation Effects: NONE

Elevation (ft) looking N

TxDOT Rock Mass Field Description
Glen Rose Formation

Summary of Engineering Geologic Data

Joint Description Summary

Set #	Strike	Dip	Roughness	Separation/ Filling	Persistence	Weathering	Remarks
1	N40 W	90°	ROUGH/UND	1/8" MAX	MOD	[illegible]	
2	N80 W	75°	ROUGH/UND	[illegible]/NO FILLING	MOD	[illegible]	
3	N 30 E	80°	ROUGH/UND	TIGHT	MOD	[illegible]	ONLY 3 SETS
							APPARENT
							BUT NUMEROUS
							[illegible] DISCS.

Other Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks

Bedding Description: A FEW THIN BEDS NEAR TOP (< 6"), BUT MOST ARE BTWN 12" & 3 FT.

Weathering: MARL LAYER [illegible] BASE IS [illegible] OUT. THIS LAYER [illegible] OUT AT ABOUT MID [illegible] OF SLOPE DUE TO GRADE OF ROAD. UPPER 3-5' [illegible] IS WEATHERED TO TAN COLOR.

Active Erosion: MARL LAYER, WATER DRIPPING FROM SOME BEDS AND FROM TOP OF SLOPE

Available Geotechnical Data:

Form of Slope Failure/Degradation: SMALL BLOCKS ALONG JOINT INTERSECTIONS, UNDERMINING AT MARL LAYER, SUBSEQUENT BLOCK FALL

Debris: GRAVEL TO 2'-3' SIZE LS FRAGMENTS

Maintenance Record: ?

Description Key:

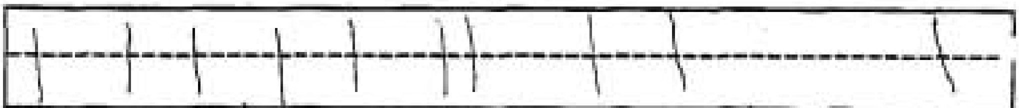
Roughness		Persistence	Water (ISRM Romana)		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TxDOT Rock Mass Field Description

Glen Rose Formation

Scanline Descriptions

Horizontal Scanline Number: 1
Horizontal Location (locate on sketch): ____________
Height above base of cut (ft): 12' → 2'
If w/in one layer, layer thickness: ________
Length of scanline (ft): 100'
Strike of scanline (if different from face): ____________



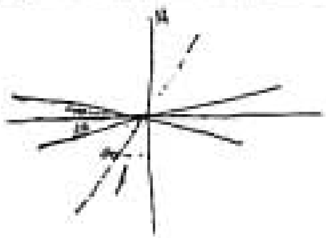
0+00 0+100 0+45 0+50 0+25 1+00 0+00

Scanline Sketch (include seepage locations)

Debris Description

obs #	Sta.	Set	Strike w/r to exposure +/-20	20-45	45-90	R/L	Dip w/r to exposure +/-20	20-45	45-90	R/L	Persist.	Cond'n	Remarks
1	0+10	1			X	L	X			—	NM	Tight/[illegible]	
2	0+37	2			X	L	X			—	NM	[illegible]	
3	0+47	1			X	L	X			—	NM	1/8" [illegible]	
4	0+52	3		X		R	X			—	NM	Tight [illegible]	
5	0+54	1			X	L	X			—	NM	open w/calc	/Large [illegible]
6	0+65	2			X	L	X			—	NM	open w/calc	/Large [illegible]
7	0+70	1			X	L	X			—	NM	Tight to	1/16" / no fill
8	0+80	2			X	L	X			—	NM	open (1/16" - 1/8" no fill, [illegible])	
9	0+86	1			X	L	X			—	NM	Tight to	[illegible]" (no fill, [illegible])
10	0+98	2			X	L	X			—	NM	open to 1/8"	no fill, [illegible]
11													
12													
13													
14													
15													
16													
17													
18													
19													
20													

Set	Apparent spacing (W/scan length)	True Spacing (W/scan length)
1	20'	18'
2	25'	16'
3	100'	64'
4		
5		

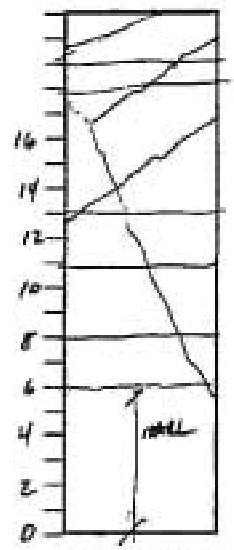


TxDOT Rock Mass Field Description

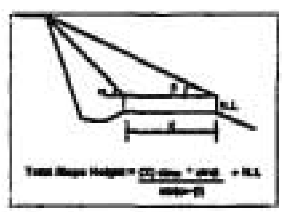
Glen Rose Formation

Scanline Descriptions

Vertical Scanline Number: 1
Scanline Location (show on sketch): STA 1+00
Height of Scanline (ft): 16'
Length of Scanline(ft): 2'



Scanline Sketch



Scanline Information:

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Cond'n	Remarks
			+/-20	20-45	45-90	R/L	+/-20	20-45	45-90	R/L			
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													
14													
15													

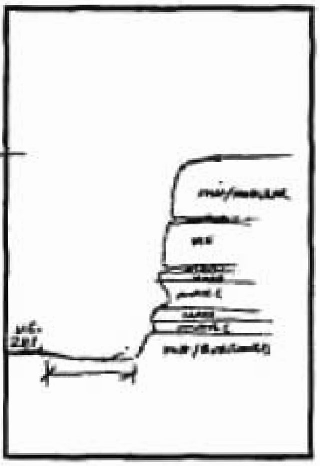
Date: 5/14/95
Page 1 of 4
Code 281-1

TxDOT Rock Mass Field Description

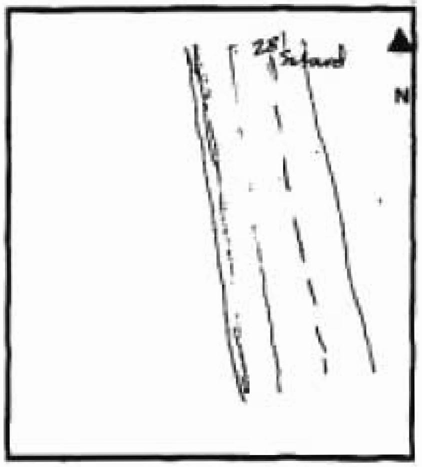
Glen Rose Formation

Location: U.S. 281 JUST SOUTH OF CIBOLO CREEK IN BEXAR CO.

TxDOT District: SAN ANTONIO



Profile Sketch



Plan Sketch

General Exposure Description

Dimensions and Orientation:

Total Height (ft): 20'

Lateral Extent (ft): 795 + 49.5 + 75' = 920

~~Benches~~ Height Width

L1

L2

L3

Face Orientation: Strike/dip: N15°W, 88° (12° LAY BACK)

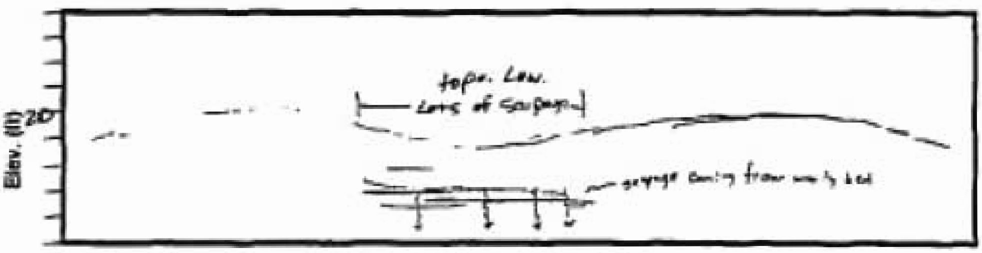
Catchment Description: DITCH, SET BACK ±20' FROM E.P.

Artificial Support: NONE

Method of Excavation (incl. effects): MECHANICAL ?

Age of Exposure: 35-40 yr.

Vegetation Effects: DEPRESSION WEED / GRASS CLUMPS GROWING FROM MARLY LAYER



Elevation (ft) looking SW

TxDOT Rock Mass Field Description
Glen Rose Formation

Summary of Engineering Geologic Data

Joint Description Summary

Set #	Strike	Dip	Roughness	Separation/ Filling	Persistence	Weathering	Remarks
1	N30W	VERT	ROUGH/PLANAR	TIGHT	BC	[illegible]	CONFINED TO HARD BED, BED ABOVE MARL
							SPACING approximately ranges FROM 4'-12'

Other Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks

Occasional Random Joints? YES, BC, LOCAL HARD BED BELOW MARL

Bedding Description: ALTERNATING HARDER & SOFTER MARLY LS (2'-4')

Weathering/Erosion: EROSION OF MARL BEDS, LARGE BLD IN MIDDLE OF EXPOSURE HAS RETREATED 2'-3' FROM FACE

Form of Slope Failure/Degradation: MINOR SPALLING / RAVELLING SOME BLOCK FALL W/ BED FROM WALL - SMALL BLOCK FALL IS ALONG JT/BED INTERSECTION.

Debris: SMALL TALUS PILE, OCC. 1'-4' BLOCKS

Maintenance Record:

Available Geotechnical Data:

TxDOT Rock Mass Field Description
Glen Rose Formation

Code 281-1

Scanline Descriptions

Horizontal Scanline Number: ____
Horizontal Location (locate on sketch): ____________________
Height above base of cut (ft): ____
If w/in one layer, layer thickness: ________
Length of scanline (ft): ________
Strike of scanline (if different from face): ____________________

0+00 0+50 1+00

Scanline Sketch (include seepage locations)

Debris Description

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Condition
			+/-20	20-45	45-60	R/L	+/-20	20-45	45-60	R/L		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												

Set	Apparent spacing (#/scan length)	True Spacing (#/scan length)
1	11'-12'	2' ±
2		
3		
4		
5		

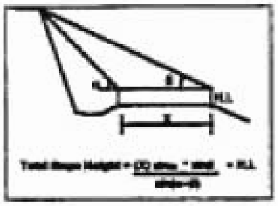
TxDOT Rock Mass Field Description
Glen Rose Formation

Scanline Descriptions

Vertical Scanline Number: ________
Scanline Location (show on sketch): ____________________
Height of Scanline (ft): ________
Lrength of Scanline(ft): ________

P-20
P-21
P-22

Scanline Sketch



Fracture frequency: ________
Est. RQD: ________

Scanline Information:

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Cond'n
			+/-20	20-45	45-60	R/L	+/-20	20-45	45-60	R/L		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												

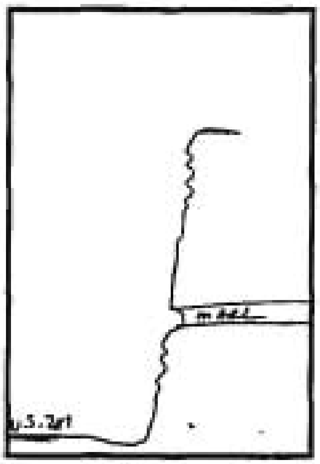
Date: 6/17/95
Page 1 of 4
Code 281-3

TxDOT Rock Mass Field Description

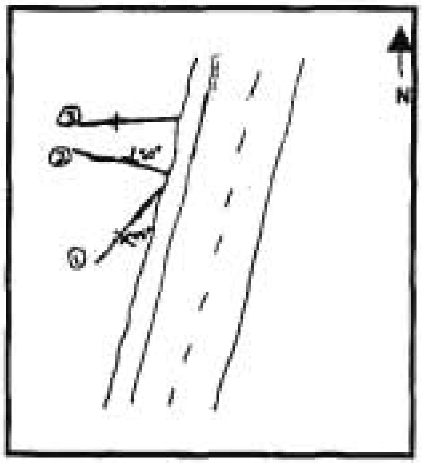
Formation: GLEN ROSE

Location: U.S. 281 SOUTH BOUND (WEST SIDE) 1/2 mi. SO. OF S.H. 46

TxDOT District: SAN ANTONIO



Profile Sketch LKG S



Plan Sketch

General Exposure Description

Dimensions and Orientation:

Total Height (ft): 35'

Lateral Extent (ft): 290 x 435 = 1250'

~~Benches:~~ Height Width

L1 ______

L2 ______

L3 ______

Face Orientation: Strike/dip: N 10°E, 75° (15° LAYBACK)

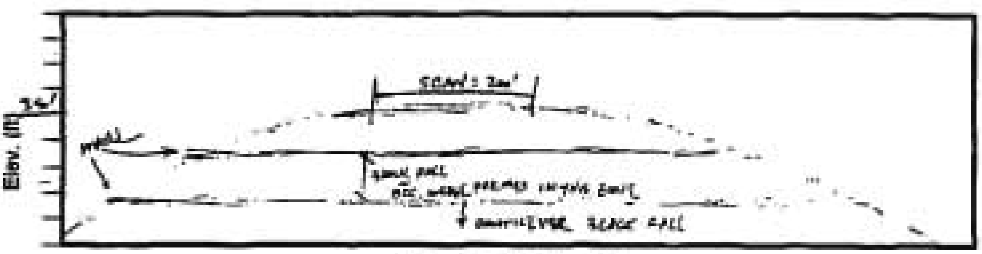
Catchment Description: SET BACK 20' FROM BOP

Artificial Support: ______

Method of Excavation (incl. effects): BLAST

Age of Exposure: ______

Vegetation Effects: SPORADIC GRASS DEV. WHERE IN MARL LAYERS



Elevation (ft) looking W

TxDOT Rock Mass Field Description

Summary of Engineering Geologic Data

Joint Description Summary

Set #	Strike	Dip	Roughness	Separation/ Filling	Persistence	Weathering	Remarks
1	N 45°E	85°SE	ROUGH	TITE	P	II	OCC. WET
2	N 70°W	50°NE	ROUGH	TITE	P	II	OCC. WET
3	N 80°E	90°	ROUGH	TITE	P	II	OCC. WET
4	BEDDING						

Other Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks

Occasional Random Joints? YES.

Bedding Description: T → B: 5' SH (SOIL-LIKE) / [illegible] 3' HARD BED, 1' MARL BED, 3' HARD, 1' MARL, 7' HARD BED, 2' MARL, 2' VERY THIN BEDS (< 2"), 2-3' HARD BEDS, 6" MARL, 2' HARD, 6" MARL, 2'+ HARD. FREQUENT SEEPS FROM MARL BEDS (DRIPPING)

Weathering/Erosion: DIFFERENTIAL WEATHERING OF MARL BEDS. MARL BED @ MID SLOPE HAS RETREATED 2' FROM FACE.

Form of Slope Failure/Degradation: OCC WEDGE OCC BLOCK FALL ALONG JOINTS BUT MOST BLOCKS ARE FROM CANTILEVER SITUATIONS ALONG THE BOTTOM 10' OF SLOPE ~~[illegible]~~

Debris: RANDOM BLOCKS, 6" → 3'

Maintenance Record:

Available Geotechnical Data:

TxDOT Rock Mass Field Description

Scanline Descriptions

Horizontal Scanline Number: 1
Horizontal Location (locate on sketch): MID SLOPE
Height above base of cut (ft): 15'
If w/in one layer, layer thickness:
Length of scanline (ft): 200' (. . .)
Strike of scanline (if different from face):

0+00 0+50 1+00

Scanline Sketch (include seepage locations)

Debris Description

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Condition
			+/-20	20-45	45-90	R/L	+/-20	20-45	45-90	R/L		
1		2			X	L		X		R	UPPER 20'	R/U/TITE/II/NO FILL/DRY
2		3			X	R	X			N/A	P	R/P/TITE/II/NO FILL/DRY
3		3			X	R	X			N/A	P	" " "/[illegible]/NO FILL/DRY
4		2			X	L		X		R	UPPER 20'	
5		1		X		R	X			L	P	VR/U/TITE/II/NO FILL/DRY
6		3			X	R	X			N/A	P	R/P/TITE/II/NO FILL/DRY
7		3			X	R	X			N/A	P	R/U/TITE/II/NO FILL/DRY
8		2			X	L		X		R	P	R/P/TITE/II/NO FILL/DRY
9		2			X	L		X		R	P	" " " " " "
10		1		X		R	X			L	P	VR/U/TITE/II/NO FILL/DRY
11		2			X	L		X		R	UPPER 20'	R/P/TITE/II/NF/DRY
12		2			X	L		X		R	"	" " "/II/NF/DRY
13		2			X	L		X		R	P	" " "/II/NF/DRY
14		1		X		R	X			L	P	R/U/TITE/II/NF/DRIPPING
15												
16												
17												
18												
19												
20												
21												
22												

Set	Apparent spacing (ft/scan length)	True Spacing (ft/scan length)
1	67'	34'
2	29'	29'
3	60'	47'
4		
5		

TxDOT Rock Mass Field Description

Scanline Descriptions

Vertical Scanline Number: ________
Scanline Location (show on sketch): ________________
Height of Scanline (ft): ________
Length of Scanline(ft): ________

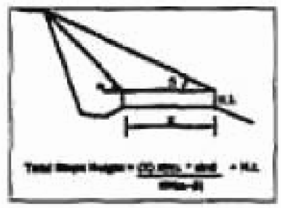


Photo Listing

No.	Description
7	ROCK FALL/CANTILEVER
8	DEBRIS + PANORAMIC LKG N
9	PAN
10	PAN
11	PAN
12	DIFF WEATHERING

Scanline Sketch

EST RQD
65-75

Samples Taken: 2 SAMPLES FOR SLAKE
(1 FROM MID-SLOPE MARLY LAYER, 1 - FROM
HARD BED JUST BELOW

Scanline Information:

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Cond'n
			+/-20	20-45	45-90	R/L	+/-20	20-45	45-90	R/L		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

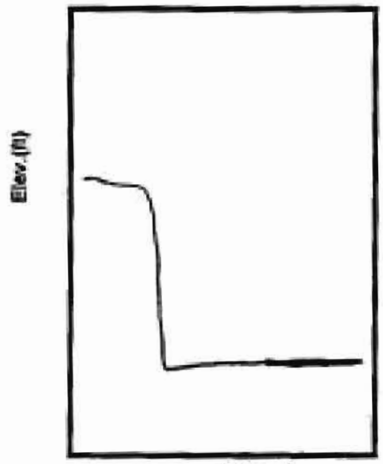
Date: 6/17
Page 1 of 4
Code 281-4

TxDOT Rock Mass Field Description

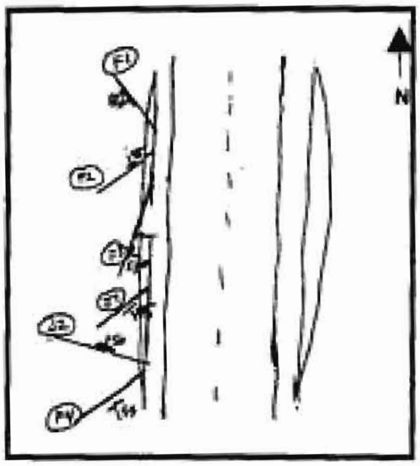
Formation: GLEN ROSE

Location: U.S. 281 5 mi south of GUADALUPE RIVER in COMAL CO.

TxDOT District: SAN ANTONIO



Profile Sketch LKG N.



Plan Sketch

General Exposure Description

Dimensions and Orientation:

Total Height (ft): 15'

Lateral Extent (ft): 140 x 4.35 = 630'

~~Benches~~: Height Width

L1 ____

L2 ____

L3 ____

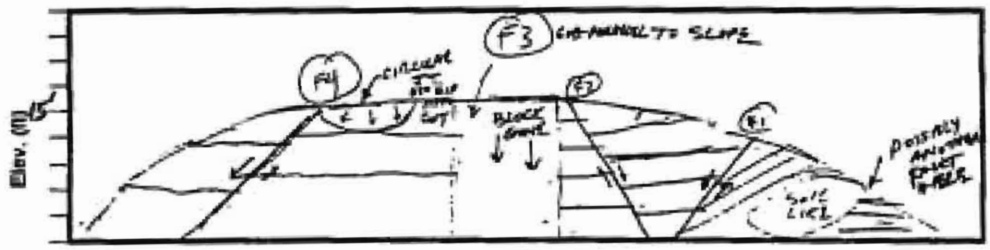
Face Orientation: Strike/dip: DUE NORTH / 78° (12° LAY BACK)

Catchment Description: SET BACK 20-22' FROM TOP

Artificial Support: NONE

Method of Excavation (incl. effects): BLAST

Age of Exposure: ____ Vegetation Effects: NONE



Elevation (ft) looking W

TxDOT Rock Mass Field Description

Summary of Engineering Geologic Data

FAULT & JOINTS
~~Joint~~ Description Summary

~~Joint~~ FRACTURE	Strike	Dip	Roughness	Separation/ Filling	Persistence	Weathering	Remarks
F1	N45°W	80°SW	VR/U	UP TO 3"	P	III	SOIL ROCK BRK FILLING
F2	N65°E	45°NW	VR/U	TIGHT TO 3"	P	II – III	[illegible] ROCK FILL
J1	N40E	45° SE	SS/U	TITE	P	I	
F3	N70°E	53°SE	R/U	TITE	P	II	LARGE BLOCK IS MISSING 40' WIDE, ABSENT OF CUT
J2	N70°W	50°NE	R/U	TITE	P	II	
F4	N65°E	55°SE	R/P	TITE → ½	P	II	SOME FINE GR. SOIL

ALL DRY

~~Other~~ Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks

Occasional Random Joints? A CIRCULAR JT. NEAR TOP OF CUT LEFT (SOUTH) OF F3 IS DIPPING 60°–85° INTO EXC. BLOCKS ARE FORMED

Bedding Description: TABS = 5' OF 1'-2' HARD BEDS, 4' NODULAR BEDS, 6' HARD NODULAR BEDS

Weathering/Erosion: JUST DISCOLORATION, NO SOFT ERODING BEDS EXCEPT LARGE POCKET OF MARLY-SOIL LIKE MATL @ N. END EROSION + SOIL LIKE SLOPE FAILURE

Form of Slope Failure/Degradation: MINOR BLOCK / WEDGE, PLANAR SOME LOOSE BLOCKS UPPER 3' OF CUT

Debris: 5 OR 6, 1'-2' BLOCKS ARE ONLY DEBRIS ALONG ENTIRE CUT

Maintenance Record:

Available Geotechnical Data:

TxDOT Rock Mass Field Description

Scanline Descriptions

Horizontal Scanline Number: 1
Horizontal Location (locate on sketch): E ST. AT J2 AND GO SOUTH 220'
Height above base of cut (ft): 6'
If w/in one layer, layer thickness: —
Length of scanline (ft): 220'
Strike of scanline (if different from face): SAME

0+00 0+50 1+00

Scanline Sketch (include seepage locations)

Debris Description

obs #	Sta.	Set	Strike w/r to exposure +/-20	20-45	45-90	R/L	Dip w/r to exposure +/-20	20-45	45-90	R/L	Persist.	Condition
1		F3	X			R		X		L	P	SLL P.Z
2	55	J1		X		R		X		L	P	TITE / R.U / II / No FILL / DRY
3	142	J2			X	L		X		R	P	TITE / R U / II / No FILL / DRY
4		F4			X	R	-	X		L	P	SLL P.Z
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												

Set	Apparent spacing (#/scan length)	True Spacing (#/scan length)	
J1	20'	13'	HHT HHT I
J2	28'	26'	HHT III
3			
4			
5			

TxDOT Rock Mass Field Description

Scanline Descriptions

Vertical Scanline Number: ________
Scanline Location (show on sketch): ________
Height of Scanline (ft): ________
Length of Scanline(ft): ________

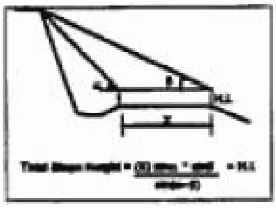


Photo Listing

No.	Description
12-17	
18	F3 CLOSE UP

Scanline Sketch

EST RQD 55-75
EXCEPT IN FAULT
ZONES

Samples Taken: CLAYS FROM ERODED SOIL POCKETS

Scanline Information:

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Cond'n
			+/-20	20-45	45-90	R/L	+/-20	20-45	45-90	R/L		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

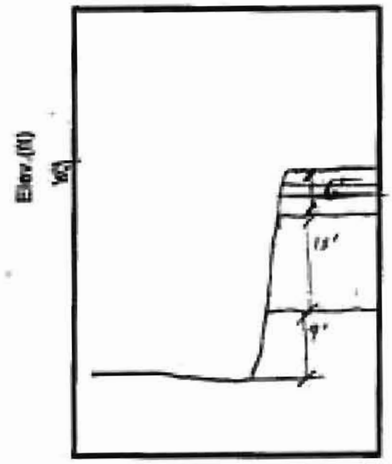
Date: 6/17
Page 1 of 4
Code 281-5

TxDOT Rock Mass Field Description

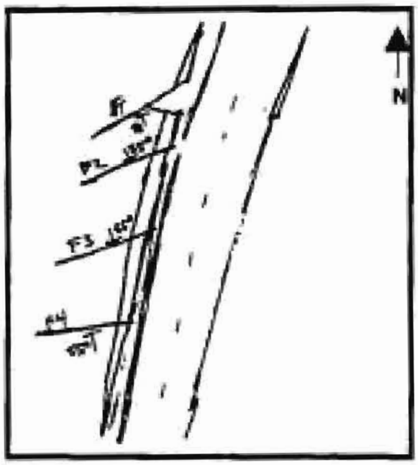
Formation: GLEN ROSE

Location: US. 281 just N. of 281-2 in Comal Co.

TxDOT District: SAN ANTONIO

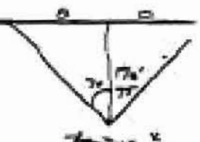


Profile Sketch LKG E.



Plan Sketch

General Exposure Description



Dimensions and Orientation:

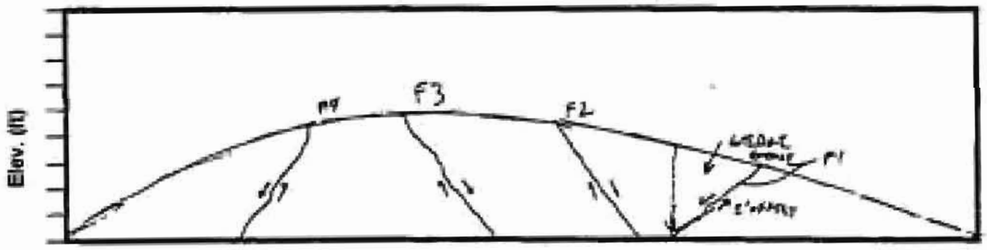
Total Height (ft): 30'
Lateral Extent (ft): 1180'
~~Benches~~ Height Width
L1
L2
L3

Face Orientation: Strike/dip: N 20°E, 78° (12° LAYBACK)
Catchment Description: SET BACK 20-25' FROM EOP
Artificial Support: NONE

Method of Excavation (incl. effects): BLAST, V. SMOOTH WALL

Age of Exposure:

Vegetation Effects: NONE



Elevation (ft) looking ___

TxDOT Rock Mass Field Description

Summary of Engineering Geologic Data

Joint Description Summary

Set #	Strike	Dip	Roughness	Separation/ Filling	Persistence	Weathering	Remarks	[illegible] CUT
J1	N85°E	55° NW	VR/U	T, T T	P	II		[illegible]
J2	N10° W	70° SW	VR/U	T, T T	P	I~a~ – II~b~		[illegible]
F1	N45° E	55° SE	SS/U	1"–6" open	P	II	No filling – source of [illegible] wedge	
J3	N65°W	90	VR/U	T, T T 2"	P	II	Some [illegible] filling	[illegible]
F2	N 55° E	55° NW	SS/U	T, T	P	II	No fill	
F3	N50° E	55° NW	SS/U	T T	P	II	No fill	
F4	N75° E	55° SE	RKS/U	T T	P	II	No fill	

Other Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks

Occasional Random Joints? YES, NEAR FAULTS GENERALLY ⊥ TO CUT VARYING FROM 45 – 90° DIP

Bedding Description: T-B: TOP 6' IS 3 - 2' BEDS, FOLLOWED BY A 15' BED and 9' BED

Weathering/Erosion: NONE

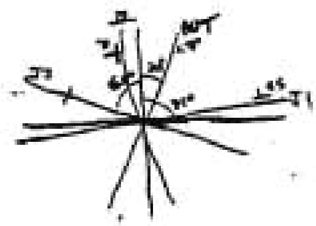
Form of Slope Failure/Degradation: 2 WEDGE PLANAR FAILURES. V. MINOR SPALLING
N. WEDGE IS 40' WIDE

Debris: NONE

Maintenance Record:

Available Geotechnical Data:

TxDOT Rock Mass Field Description



Scanline Descriptions

Horizontal Scanline Number: 1
Horizontal Location (locate on sketch): BNTIER CUT
Height above base of cut (ft): 10'
If w/in one layer, layer thickness: ______
Length of scanline (ft): 1100'
Strike of scanline (if different from face): ______

0+00 0+50 1+00

Scanline Sketch (include seepage locations)

Debris Description

obs #	Sta.	Set	Strike w/r to exposure +/-20	20-45	45-90	R/L	Dip w/r to exposure +/-20	20-45	45-90	R/L	Persist.	Condition
1		J1			X	R		X		R	P	TITL / [illegible] / U / DRY / II / NO FILL
2		J2		X		L	X			L	P	[illegible] / [illegible] / U / DRY / [illegible] / NO FILL
3		J3			X	L	X			N/A	P	[illegible] / [illegible] / U / DRY / [illegible]
4		F1		X		R		X		L	P	1"-6" / SS / U / II / NO FILL / DRY
5		F2		X		R		X		R	P	TITL / SS / U / II / NO FILL / DRY
6		F3		X		R		X		R	P	TITL / [illegible] / U / II / NO FILL / DRY
7		F4			X	R		X		L	P	TITL / [illegible] / U / II / NO FILL / DRY
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												

Set	Apparent spacing (ft/scan length)	True Spacing (ft/scan length)
J1	220'	390'
J2	122'	61'
J3	138'	137'
4		
5		

TxDOT Rock Mass Field Description

Scanline Descriptions

Vertical Scanline Number: ________
Scanline Location (show on sketch): ________
Height of Scanline (ft): ________
Length of Scanline(ft): ________

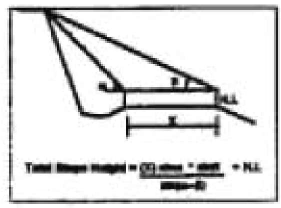


Photo Listing

No.	Description
22	WEDGE (NORTH)
23	WEDGE (SOUTH)
1	WEDGE N.
2	PANORAMIC LEG SW
3	WEDGE S.
4	PANORAMIC LEG N

Scanline Sketch

EST RQD
90-100

Samples Taken: NONE

Scanline Information:

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Cond'n
			+/-20	20-45	45-60	R/L	+/-20	20-45	45-60	R/L		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

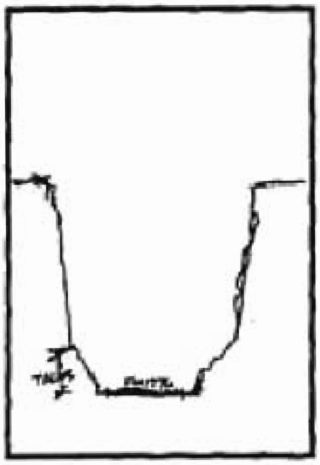
TxDOT Rock Mass Field Description

Formation: GLEN ROSE

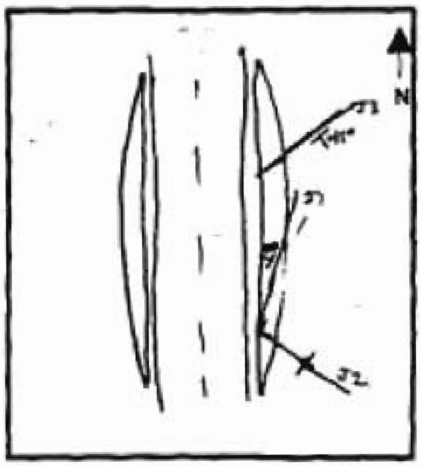
Location: FM 1376, 6 mi NORTH OF BOERNE

TxDOT District: SAN ANTONIO

Elev. (ft)



Profile Sketch



Plan Sketch

General Exposure Description

Dimensions and Orientation:

Total Height (ft): 45'

Lateral Extent (ft): 95 + 35 + 50' = 180'

~~Benches~~ Height Width

L1

L2

L3

Face Orientation: Strike/dip: DUE NORTH / VARIES 75°-80° (10°-15° LAYBACK)

Catchment Description: SET BACK ONLY 10' FROM ROAD

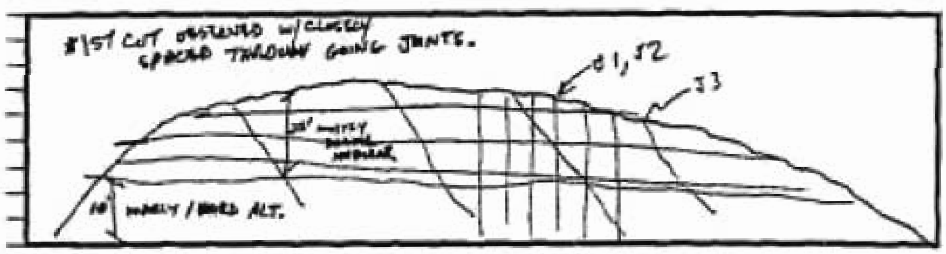
Artificial Support: NONE

Method of Excavation (incl. effects): ASSUME BLAST

Age of Exposure:

Vegetation Effects: LOTS OF VEG LOWER 10' OF SLOPE WHICH IS MOSTLY TALUS FROM ABOVE

Elev. (ft)



Elevation (ft) looking EAST

TxDOT Rock Mass Field Description

Summary of Engineering Geologic Data

Joint Description Summary

Set #	Strike	Dip	Roughness	Separation/ Filling	Persistence	Weathering	Remarks
1	N 20°E	80 NW	R/P-U	TIGHT to 1/4"	P	II	
2	N 50°W	90	R/P-U	TIGHT to 1/4"	GENERALLY P	II	
3	N 40°E	45°SE	R/U	TIGHT to 1/2"	P	II	
4	BEDDING						

Other Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks

Occasional Random Joints? NO

Bedding Description: UPPER 25' IS 1'-4' BEDS (MOSTLY RESISTIVE), LOWER 10' HAS MARLY BEDS (1'-3') INTERBEDDED WITH HARD, RESISTIVE [illegible]. VERY BLOCKY. JT SETS 1, 2 VERY CLOSELY SPACED

Weathering/Erosion: TYPICAL DIFF. EROSION OF HARD/SOFT BEDS, NO DRAMATIC RETREAT BACK FROM FACE. NO SEEPAGE OBSERVED BUT WEST DITCH IS WET AND VEGETATION IS VERY GREEN ∴ MUST BE SEASONAL SEEPAGE COMING OUT SOMEWHERE AROUND TOE.

Form of Slope Failure/Degradation: RAVELLING; LARGE TALUS BUILT UP @ THE TOE; SMALL BLOCKS

Debris: SOIL LIKE TALUS AT BASE, + OCC 4"-1' BLOCKS. LOOKS LIKE DITCH HAS BEEN CLEANED RECENTLY

Maintenance Record:

Available Geotechnical Data:

TxDOT Rock Mass Field Description

Scanline Descriptions

Horizontal Scanline Number: 1
Horizontal Location (locate on sketch): BATTLE CUT (EAST FACE)
Height above base of cut (ft): 25'
If w/in one layer, layer thickness: ______
Length of scanline (ft): ENTIRE CUT (480')
Strike of scanline (if different from face): ______

0+00 0+50 1+00

Scanline Sketch (include seepage locations)

Debris Description

obs #	Sta.	Set	Strike w/r to exposure: +/-20	20-45	45-90	R/L	Dip w/r to exposure: +/-20	20-45	45-90	R/L	Persist.	Condition
1		1		X		R	X			L	P	[illegible] T.T8/R/P/II/DRY
2		2			X	L	X			N/A	P	" " " " "
3		3		X		R		X		R	P	TITL T. 1/2"/R/U/II/DRY
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												

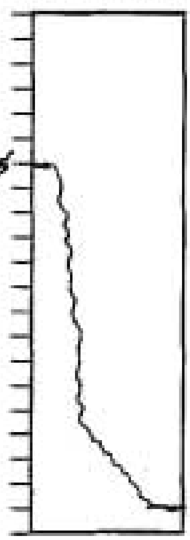
Set	Apparent spacing (ft/scan length)	True Spacing (ft/scan length)	
1		1'-5'	[illegible]
2		1'-3'	[illegible]
3	66'	42'	7/cut
4			
5			

TxDOT Rock Mass Field Description

Scanline Descriptions

Vertical Scanline Number: ________
Scanline Location (show on sketch): ____________________
Height of Scanline (ft): ________
Length of Scanline(ft): ________

35'



Scanline Sketch

BST RQD
BEHIND FACE
≥ 40-60

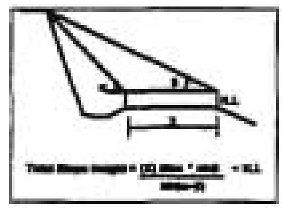


Photo Listing

No.	Description
19	J1, J3
20	WEST FACE
24	[illegible] FACE

Samples Taken: NONE

Scanline Information:

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Cond'n
			+/-20	20-45	45-60	R/L	+/-20	20-45	45-60	R/L		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

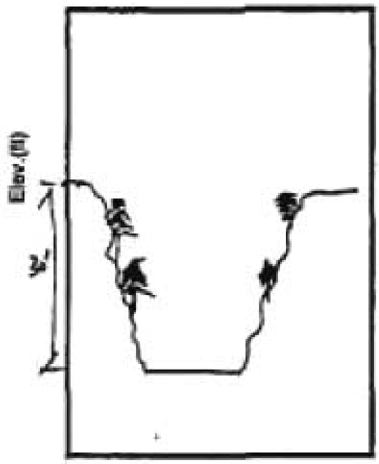
Date: 6/23/95
Page 1 of 4
Code 1376-2

TxDOT Rock Mass Field Description

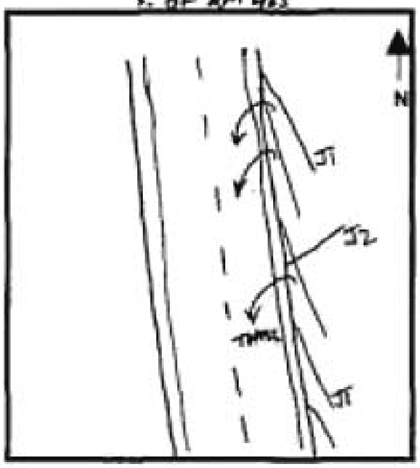
Formation: GLEN ROSE

Location: FM 1376 2 mi SOUTH OF FM 473 IN KENDALL CO. S. OF FM 465

TxDOT District: SAN ANTONIO



Profile Sketch



Plan Sketch

General Exposure Description

Dimensions and Orientation:

Total Height (ft): 30'

Lateral Extent (ft): .2 mi = 1000'±

~~Benches~~ Height Width

L1 ______

L2 ______

L3 ______

Face Orientation: Strike/dip: N5°W, VARIES 20°-25° LAY BACK

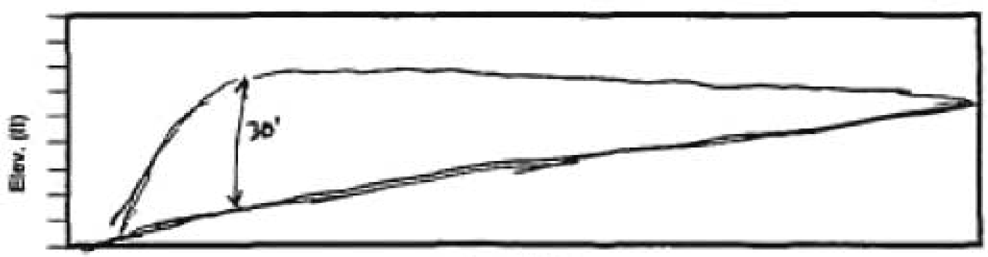
Catchment Description: TOE AT E.O.P. - NO SET BACK 10' PAVED SHOULDER

Artificial Support: NONE

Method of Excavation (incl. effects): BLAST. VERY ROUGH SLOPE, NO SHOT HOLES OBSERVED

Age of Exposure: ______

Vegetation Effects: LOTS OF BRUSH & TREES IN SLOPE.



Elevation (ft) looking ___

TxDOT Rock Mass Field Description

Summary of Engineering Geologic Data

Joint Description Summary

Set #	Strike	Dip	Roughness	Separation/ Filling	Persistence	Weathering	Remarks
1	N 15° W	90°	SL. ROUGH	TI-TII	P	II	
2	N 40° E	90°	ROUGH	TIII, ≥5mm	BC.	II-III	BED CONFINED / ABUTTING

Other Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks

Occasional Random Joints? MANY FRACTURES AROUND TREE BASES

Bedding Description: 2'-5' HARDER NODULAR BEDS W/ OCC. THIN MARLY SEAMS (<6"). BLOCKY APPEARANCE

Weathering/Erosion: V. LITTLE. MARLY SEAMS HAVE ERODED SLIGHTLY.

Form of Slope Failure/Degradation: BLOCK → TOPPLING ALONG JT SET #1

Debris: V. LITTLE 3"-8" SIZE ROCKS

Maintenance Record:

Available Geotechnical Data:

TxDOT Rock Mass Field Description

Scanline Descriptions

Horizontal Scanline Number: ____ NOT DONE
Horizontal Location (locate on sketch): ____________
Height above base of cut (ft): _____
If w/in one layer, layer thickness: _______
Length of scanline (ft): _______
Strike of scanline (if different from face): ____________

0+00 0+50 1+00

Scanline Sketch (include seepage locations)

Debris Description

obs #	Sta.	Set	Strike w/r to exposure +/-20	Strike w/r to exposure 20-45	Strike w/r to exposure 45-60	Strike w/r to exposure R/L	Dip w/r to exposure +/-20	Dip w/r to exposure 20-45	Dip w/r to exposure 45-60	Dip w/r to exposure R/L	Persist.	Condition
1		1	X			L	X			N/A	P	SL. ROUGH / P-U / TIGHT / II / DRY
2		2		X		R	X			N/A	[illegible]	ROUGH / U / TIGHT → 5mm / II / DRY
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												

Set	Apparent spacing (#/scan length)	True Spacing (#/scan length)
1	-	2-4'
2	Random	
3		
4		
5		

VARIES, MEASURED W/TAPE

TxDOT Rock Mass Field Description

Scanline Descriptions

Vertical Scanline Number: ________
Scanline Location (show on sketch): ________
Height of Scanline (ft): ________
Length of Scanline(ft): ________

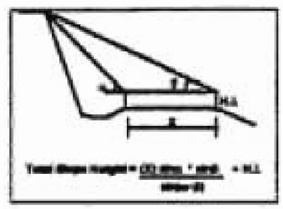


Photo Listing

No.	Description
	NONE - FORGOT CAMERA

Scanline Sketch

Samples Taken: NONE

EST. RQD
60-80

Scanline Information:

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Cond'n
			+/-20	20-45	45-60	R/L	+/-20	20-45	45-60	R/L		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

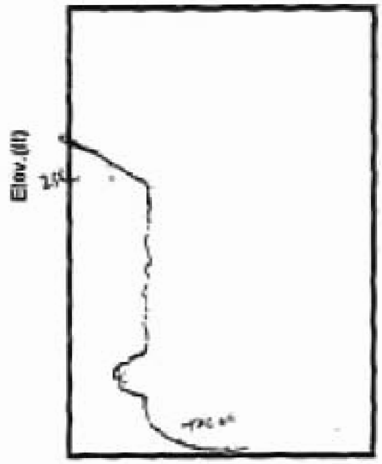
Date: 5/14/95
Page 1 of 4
Code I-10-5

TxDOT Rock Mass Field Description

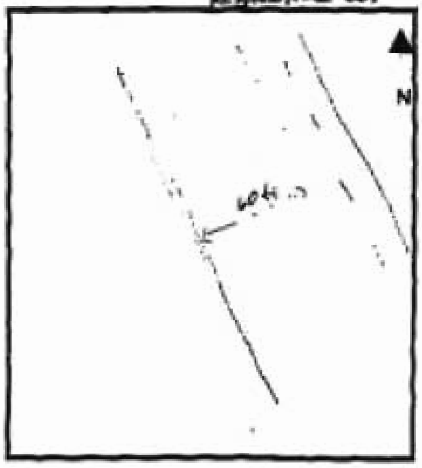
Glen Rose Formation

Location: I-10 EASTBOUND ON FRONTAGE RD JUST W OF FM 289 (WELFARE) KENDALL CO.

TxDOT District: SAN ANTONIO



Profile Sketch



Plan Sketch

General Exposure Description

Dimensions and Orientation:

Total Height (ft): 25'

Lateral Extent (ft): 105 x 4.35 =

~~Benches~~: Height ~~to~~ Width

L1

L2

L3

Face Orientation: Strike/dip: N 70 W / VERTICAL

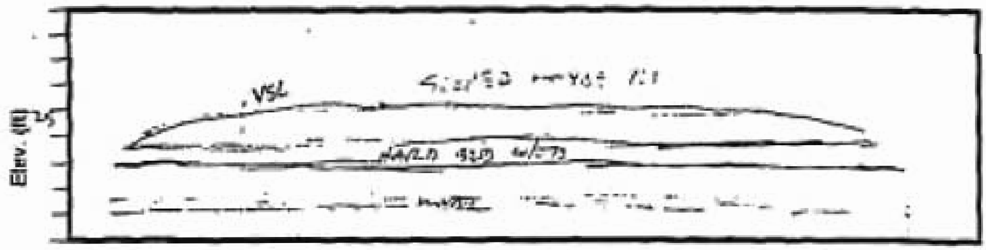
Catchment Description: NONE, SET BACK 13 x 4.35 ft from EOP

Artificial Support: NONE

Method of Excavation (incl. effects): PROBABLY BLAST BUT NO EVIDENCE OF SHOT HOLES

Age of Exposure:

Vegetation Effects: N/A



Elevation (ft) looking SW

TxDOT Rock Mass Field Description
Glen Rose Formation

Summary of Engineering Geologic Data

Joint Description Summary

Set #	Strike	Dip	Roughness	Separation/ Filling	Persistence	Weathering	Remarks
1	N 60 W	85° NW	R/P	TITE	BC	[illegible]	CONFINED TO HARD LAYER
2	N 15° E	80° NW	R/P	TITE	BC	DECAY	ALONG MARL
							J1 SPACING 1/3'
							J2 SPACING 1/4'

Other Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks

Occasional Random Joints? YES, BC

Bedding Description: @ MAX HT: 3' MH BED, 4" MARLY, 3' MH, 6" MARLY, 3-4' HARD WHITE, 4" MARLY, 3' MH, 3' VH

Weathering/Erosion: MARL BED HAS ERODED UP TO 3.5 FT BACK FROM FACE

Form of Slope Failure/Degradation: BLOCK FALL IN HARD BEDS ABOVE MARL DUE TO TENSILE FAILURE, JOINTS SEEM TO [illegible] CONTROL. ~~[illegible]~~ MINOR SPALLING/RAVELLING OTHERWISE

Debris: TYPICAL FINE TALUS AROUND OCC. 1'-3' BLOCKS; HAVE FALLEN UP TO 12' FROM FACE

Maintenance Record:

Available Geotechnical Data:

TxDOT Rock Mass Field Description
Glen Rose Formation

Page 3 of ___
Code I-10-5

Scanline Descriptions

Horizontal Scanline Number: ____
Horizontal Location (locate on sketch): ____________________
Height above base of cut (ft): _____
If w/in one layer, layer thickness: _______
Length of scanline (ft): __________
Strike of scanline (if different from face): ____________________

0+00 0+50 1+00

Scanline Sketch (include seepage locations)

Debris Description

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Condition
			+/-20	20-45	45-90	R/L	+/-20	20-45	45-90	R/L		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												

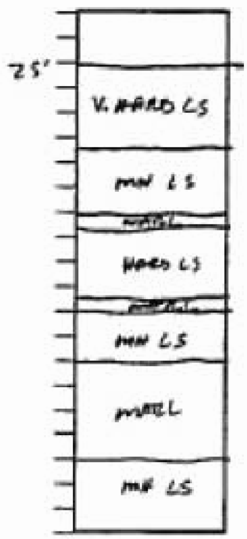
Set	Apparent spacing (#/scan length)	True Spacing (#/scan length)
1		
2		
3		
4		
5		

TxDOT Rock Mass Field Description
Glen Rose Formation

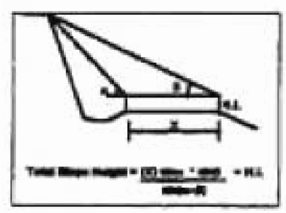
Scanline Descriptions

Vertical Scanline Number: 1
Scanline Location (show on sketch): ____________
Height of Scanline (ft): ________
Lrength of Scanline(ft): ________

P-17
P-18
P19



Scanline Sketch



Fracture frequency: ________
Est. RQD: 60-75 IF MARL IS RECOVERED

Scanline Information:

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Cond'n
			+/-20	20-45	45-90	R/L	+/-20	20-45	45-90	R/L		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												

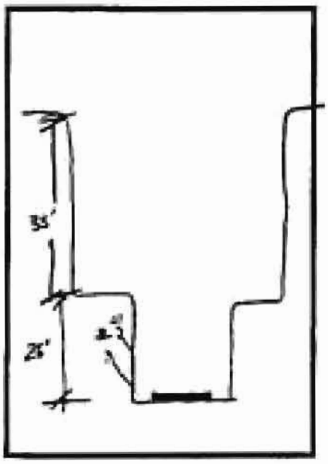
Date: 6/17
Page 1 of 4
Code 2722-1

TxDOT Rock Mass Field Description

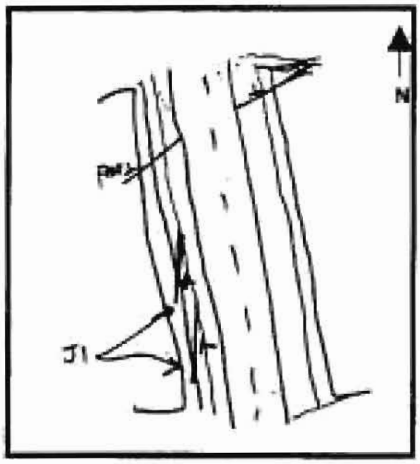
Formation: GLEN ROSE

Location: FM 2722 BTWN FM 2673 AND S.H. 46. (BEAR CREEK)

TxDOT District: SAN ANTONIO



Profile Sketch LKG- EA



Plan Sketch

General Exposure Description

Dimensions and Orientation:

Total Height (ft): 61'
Lateral Extent (ft): 83 × 4.35' = 360'

Benches / Height	Width
L1 35'	12'
L2 26	
L3	

Face Orientation: Strike/dip: N 12°W, NO LAYBACK (90°)
Catchment Description: SET BACK 30' FROM EOP
Artificial Support: NONE

Method of Excavation (incl. effects): BLAST, APPEARS FRESH < 3 YRS

Age of Exposure: ______

Vegetation Effects: NONE

Elevation (ft) looking SW

TxDOT Rock Mass Field Description

Summary of Engineering Geologic Data

Joint Description Summary

Set #	Strike	Dip	Roughness	Separation/ Filling	Persistence	Weathering	Remarks
1 JT (I)	[illegible]	55° E	SS/U	T1T1	P	II	DRY
1 JT (II)	N 12 W	50 NE	SS/U	T1T2	P	II	DRY
FAULT	N45°E	60 NW	?	?	P	VI	RIGHT OF FAULT IS ALL SOIL LIKE (SWLS); ROCK PIECES IN RED CLAY MATRIX

Other Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks

Occasional Random Joints? J1 CUTS UP THROUGH BENCH AND OUT TOP OF BENCH
J2 UNDULATES 2'-4' ABOVE BASE

Bedding Description: NO MARLY BEDS OBSERVED, BED THICKNESS 2'-5'
NO DISCERNABLE BEDDING N. OF FAULT. HARD RED CLAY W/ ROCK FRAGS
CAN EASILY EXCAVATE W/ HAND PICK (LIKE SOIL) SEE P-10

Weathering/Erosion: NONE EXCEPT IN AREA N. OF FAULT, LOOKS LIKE K?? BECAUSE OF THE RED CLAY IN THE ROCK BUT NO SLOPE TYPE FAILURE, ACTUALLY IT IS STANDING WELL ON A VERTICAL SLOPE

Form of Slope Failure/Degradation: MINOR RAVELLING, ETC. ROCK MAINLY AT EDGE WHERE THERE ARE LOOSE BLOCKS @ TOP OF BOTH SLOPES

Debris: BENCH: GRAVEL TO 3' BOULDER, MOST < 1' AND MAINLY IS AT RAS WHERE BLOCKS ARE LOOSE
TOE: V. LITTLE GRAVEL TO COBBLES

Maintenance Record:

Available Geotechnical Data:

TxDOT Rock Mass Field Description

Scanline Descriptions

Horizontal Scanline Number: ____
Horizontal Location (locate on sketch): ____________________
Height above base of cut (ft): _____
If w/in one layer, layer thickness: ________
Length of scanline (ft): ________
Strike of scanline (if different from face): ____________________

0+00 0+50 1+00

Scanline Sketch (include seepage locations)

Debris Description

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Condition
			+/-20	20-45	45-60	R/L	+/-20	20-45	45-60	R/L		
1		1	X			R			X	R	P	
2		2	X			N/A			X	N/A	P	
3												
4												
5												
6												
7												
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11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												

Set	Apparent spacing (#/scan length)	True Spacing (#/scan length)
1		
2		
3		
4		
5		

TxDOT Rock Mass Field Description

Summary of Engineering Geologic Data

Joint Description Summary

Set #	Strike	Dip	Roughness	Separation/ Filling	Persistence	Weathering	Remarks
Random	N40°W	90		TITL	P	I	
1	N30°E	60°SE	R/HS - UND	TITL	P	II	
2	N30°E	60°NW	R/U	TITL	P	I	

Other Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks

Occasional Random Joints? YES 1 JT N 40°W, 90° R/U TITL, II, P, DRY

Bedding Description: T→B: 2' SOIL, 3' VERY [illegible], 2' FRACTURED w/ [illegible] POCKETS, 5' HARD [illegible], 6" HARD [illegible], 7' HARD [illegible], 1'+ HARD [illegible]

Weathering/Erosion: [illegible] SEEPS FROM CLAYEY BED NEAR TOP OF SLOPE. NONE ALONG JOINTS.

Form of Slope Failure/Degradation: V. MINOR SPALLING, OCC. LOOSE BLOCK FROM TOP

Debris: NONE

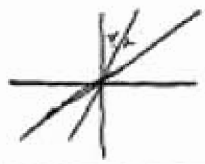
Maintenance Record:

Available Geotechnical Data:

TxDOT Rock Mass Field Description

Scanline Descriptions

Horizontal Scanline Number: 1
Horizontal Location (locate on sketch): ENTIRE CUT
Height above base of cut (ft): 6'
If w/in one layer, layer thickness: ~~8'~~
Length of scanline (ft): 1200
Strike of scanline (if different from face): ______



0+00 0+50 1+00
Scanline Sketch (include seepage locations)

Debris Description

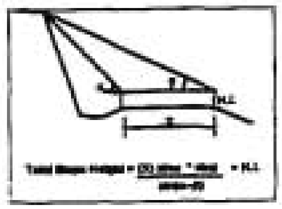
Obs #	Sta.	Set	Strike w/r to exposure +/-20	20-45	45-90	R/L	Dip w/r to exposure +/-20	20-45	45-90	R/L	Persist.	Condition
1		1		X		L	X			L	P	T-T/R/U/UND/DRY/II/No FILL
2		2		X		L	X			R	P	T-T/R/U/DRY/II/No FILL
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												

Set	Apparent spacing (#/scan length)	True Spacing (#/scan length)
1	1200/8 = 150'	63'
2	1200/4 = 300'	127'
3		
4		
5		

TxDOT Rock Mass Field Description

Scanline Descriptions

Vertical Scanline Number: ________
Scanline Location (show on sketch): ________________
Height of Scanline (ft): ________
Length of Scanline(ft): ________



Scanline Sketch

EST. RQD
80-100

Photo Listing

No.	Description
5	PANORAMIC

Samples Taken: ________________

Scanline Information:

obs #	Sta.	Set	Strike wr to exposure				Dip wr to exposure				Persist.	Cond'n
			+/-20	20-45	45-90	R/L	+/-20	20-45	45-90	R/L		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

Date: 5/13/95
Page 1 of 4
Code I10-1

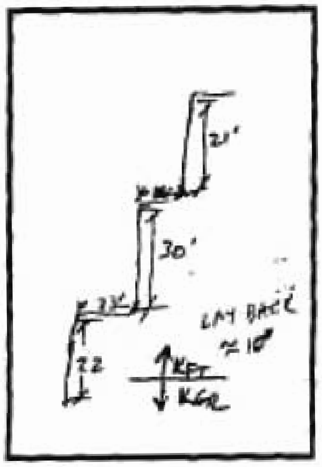
TxDOT Rock Mass Field Description

Glen Rose Formation + Fort Terrett

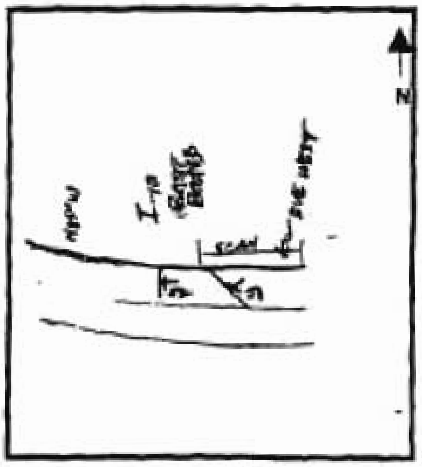
Location: I-10 (EASTBOUND SIDE) 1/2 mi Ea. of S.H. 16 (KERRVILLE)

TxDOT District: SAN ANTONIO

Elev. (ft)



Profile Sketch



Plan Sketch

General Exposure Description

Dimensions and Orientation:

Total Height (ft): 73'

Lateral Extent (ft): 230 straight + 155 = 385'

Benches:	Height	Width
L1	22	23
L2	30	16
L3	21	—

Face Orientation: Strike/dip: N 85° W @ W END TO DUE WEST @ EAST END, 80° N

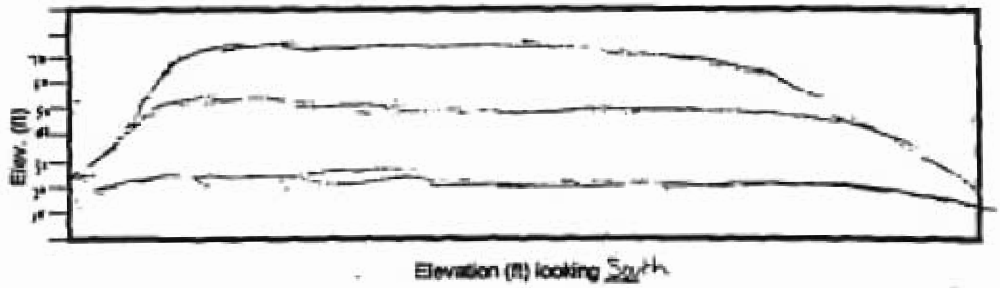
Catchment Description:

Artificial Support: NONE

Method of Excavation (incl. effects): BLAST

Age of Exposure: ______

Vegetation Effects: 8-10' CEDAR + SMALL BRUSH GROWING ON BENCHES



Elevation (ft) looking South

TxDOT Rock Mass Field Description

Glen Rose Formation

Summary of Engineering Geologic Data

Joint Description Summary

Set #	Strike	Dip	Roughness	Separation/ Filling	Persistence	Weathering	Remarks
1	N65° W	90°	[illegible]	[illegible] to 2"	P	II	Damp to WET
2	N 20° W	90°	Rough	TITE	P	III	DRY

Other Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks

Occasional Random Joints? THIN BRITTLE BEDS ARE "MICRO JOINTED" RESULTING IN [illegible] SMALL BLOCKS. RANDOM VERT JOINTS ⊥ TO SLOPE IN LOWER BENCH. 1 LG. JOINT N35°E, DIP 40° NW WET, TITE

Bedding Description: UPPER SLOPE IS [illegible] INTERBEDDED BRITTLE, THIN (1"-4") WITH THICK BEDS (2'-4'). DEBRIS COMES FROM THIN BEDS. MIDDLE IS ONE MASSIVE BED w/ A 2' MARLY BED AT BASE. MASSIVE BED HAS SOME VUGGINESS. 3 BEDS COMPRISE LOWER SLOPE. UPPER BED IS [illegible]' THICK [illegible], NEXT IS [illegible]' [illegible] THAN 2-3' MARLY BED

Weathering/Erosion: MARLY BED @ BASE HAS ERODED BACK 2' [illegible] [illegible] @ LS/MARL INTERFACE ([illegible] 1/5"-10")

Form of Slope Failure/Degradation: SPALLING / RAVELING. VERY LITTLE BLOCK FAILURE. BLOCK FAILURES ARE AT INTERSECTION OF JT SET 1 AND SLOPE [illegible] TOP OF LOWER SLOPE, APPEAR TO BE OLD BLOCK FAILS BECAUSE OF STAINING/~~WEATHERING~~

Debris: UPPER BENCH: LOTS OF 3" - 2' PLATY BLOCKS. MIDDLE BENCH VERY LITTLE COBBLE TO SMALL (1') BOULDER. LOWER: VERY LITTLE DEBRIS SIZE [illegible]

Maintenance Record:

Available Geotechnical Data:

TxDOT Rock Mass Field Description
Glen Rose Formation

Code I-10-1

Scanline Descriptions

Horizontal Scanline Number: ____
Horizontal Location (locate on sketch): ST. 75 PACES WEST OF EB. END AND GOING EAST
Height above base of cut (ft): 5'
If w/in one layer, layer thickness: ______
Length of scanline (ft): 313'
Strike of scanline (if different from face): ______

$\frac{326'}{75 \text{ paces}} = 4.35'/\text{pace}$

J1

PACES

0+00 — 0+50 — 1+00

75 PACES → 326'

Scanline Sketch (include seepage locations)

Debris Description

obs #	Sta. PACES/FT (approx. ft)	Set	Strike w/r to exposure +/-20	20-45	45-90	R/L	Dip w/r to exposure +/-20	20-45	45-90	R/L	Persist.	Condition
1	0/	J1		X		L	X			R	P	PLANAR/ROUGH/DRY/II, TITE
2	10/43.5	J1		X		L	X			R	P	" " " " "
3	15/62	J2			X	L	X			R	P	" " " " "
4	17/74	J1		X		L	X			R	P	" " " "
5	28/122	J2			X	L	X			R	P	" " " "
6	30/131	J1		X		L	X			R	P	" " " "
7	34/148	J1		X		L	X			R	P	" " " "
8	37/161	J2			X	L	X			R	P	" " " "
9	46/200	J1		X	X	L	X			R	P	"/" / [illegible] / [illegible]
10	49/213	J2		\	X	L	X			R	P	P/R/DRY/II, TITE
11	53/231	J2			X	L	X			R	P	" " " "
12	57/232	J2			X	L	X			L	P	" " " "
13	67/291	J1		X	X	L	X			R	P	P/R/DRY/[illegible] 6" [illegible]
14	72/313	J2			X	L	X			R	P	P/R/DRY/ TITE
15												
16												
17												
18												
19												
20												

Set	Apparent spacing (#/scan length)	True Spacing (#/scan length)
1	AVG. 47'	AVG. 43'
2	AVG. 44'	AVG. 41
3		
4		
5		

N65W
N20W

60
48
52
39
20
30
61

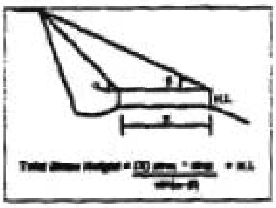
TxDOT Rock Mass Field Description

Glen Rose Formation

Scanline Descriptions

Vertical Scanline Number: ________
Scanline Location (show on sketch): ____________________
Height of Scanline (ft): ________
Lrength of Scanline(ft): ________

P-13 DEBRIS @ 2nd Bench
P-14 UPPER BENCH LKG W
P-15 JT SET NO.1
P-16 JT SET NO.1
P-17 DEBRIS LKG SW
P-18 WAVEY BED S-1



Fracture frequency: ________
Est. RQD: ________

Scanline Sketch

Scanline Information:

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Cond'n
			+/-20	20-45	45-90	R/L	+/-20	20-45	45-90	R/L		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												

Date: 5/13/98
Page 1 of 4
Code I-10-5

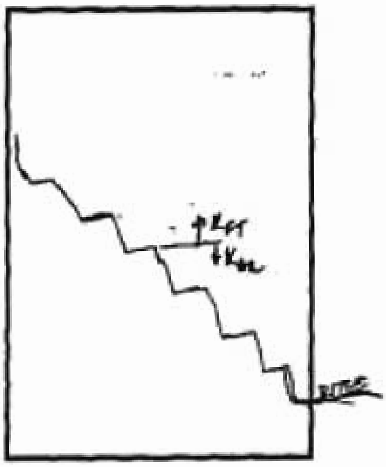
TxDOT Rock Mass Field Description

Glen Rose Formation

Location: I-10 @ CYPRESS CREEK (SE OF KERRVILLE)

TxDOT District: SAN ANTONIO

Elev. (ft)



Profile Sketch

N

Plan Sketch

General Exposure Description

Dimensions and Orientation:

Total Height (ft): 70' ±
Lateral Extent (ft): 275 ± 4.35 ≈ 1200
Benches: (5) Height Width SEE ATTACHED
L1 ______
L2 ______
L3 ______
Face Orientation: Strike/dip: DIP. WEST / N/A
Catchment Description: CONCRETE DITCH
Artificial Support: NONE

Method of Excavation (incl. effects): MECHANICAL

Age of Exposure: ______ Vegetation Effects: LOTS OF VEG. ON LOWER 3 BENCHES

Elev. (ft)

SEE PHOTOS

Elevation (ft) looking ___

TxDOT Rock Mass Field Description
Glen Rose Formation

Summary of Engineering Geologic Data

Joint Description Summary

Set #	Strike	Dip	Roughness	Separation/ Filling	Persistence	Weathering	Remarks

Other Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks

Occasional Random Joints? NONE OBSERVED, TOO WEATHERED

Bedding Description:

Weathering/Erosion: WEATHERING OF SOFTER BEDS IN Kgr

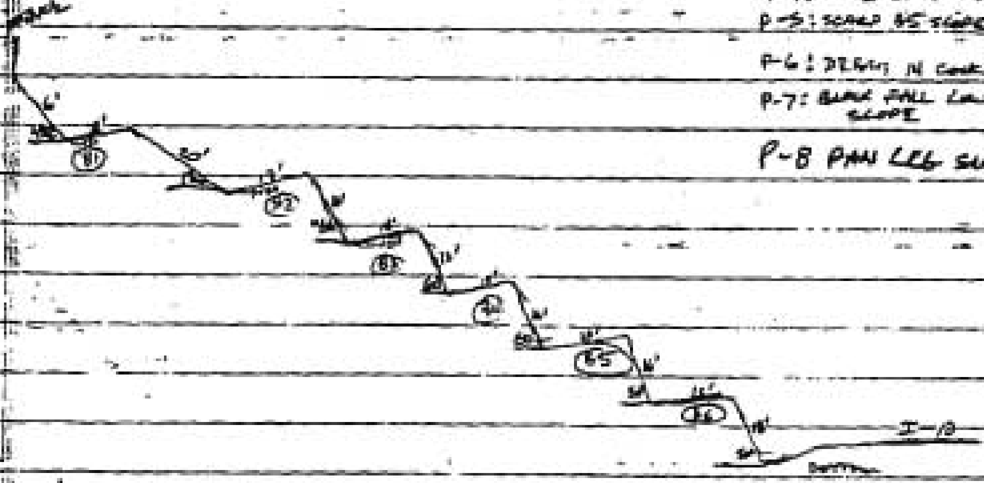
Form of Slope Failure/Degradation: A COUPLE OF CLASSICAL "SOIL TYPE" SLOPE FAILURES IN BENCHES OF SOFTER MATERIAL, OTHERWISE RAVELLING, WATER-RUTTING

Debris:

Maintenance Record:

Available Geotechnical Data:

P-1: [illegible]
P-2: [illegible]
P-3: 34 [illegible]
P-4: [illegible]
P-5: [illegible]
P-6: [illegible]
P-7: [illegible] FALL [illegible] SLOPE
P-8 PAN LEG SW



"70'"

B2+SLOPE: SLOPE HAS APX. 2' RESISTANT HARD INTACT BED
REST OF SLOPE IS WEATHERED TO GRAVEL/COBBLES, BENCH
HAS MINOR GRAVEL - COBBLE SIZE DEBRIS OCCASIONAL DEPRESSION WEED
& MINOR CLUMPS OF GRASS, OLD SLOPE FAILURE.

B3+SLOPE: HARD VUGGY BED @ WEST END W/VIRTUALLY LITTLE DEGRADATION,
SOFTER MARLY LAYERS OUTCROP BELOW THIS TO THE EAST AND ARE
RAVELED BUT ROCK STRUCTURE IS STILL VISIBLE @ TOP OF SLOPE. WEATHERED
GRAVEL/COBBLE SLOPE (1:1) BELOW THESE BEDS. BENCH DEBRIS IS
GRAVEL TO OCCASIONAL 2' BOULDER. LOTS OF DEPRESSION WEED, GRASS
BELOW MARL LAYER TO WEST IS HARDER BED W/BLOCK FALL 2'-4'

B4+SLOPE: INTERBEDDED HARD/SOFT, MINOR BLOCK FALL 1/2'-3', ABUNDANT VEG.
B5+SLOPE: MAJOR SLIDE IN SLOPE; ROTATIONAL W/3' SCARP 80' WIDE,
BENCH HEAVILY VEGETATED LARGE BLOCKS UP TO 4' (B5-1)
B6+SLOPE: BLOCK FALL, RAVELLING (BLOCKS 1'-3'), HEAVILY VEGETATED.
BENCH IS VERY WET FROM SEEPAGE APPEARS TO STAY WET.

LOWER SLOPE: LOWER SLOPE IS INTERBEDDED LIKE OTHER W/BLOCK FALLS
ABOVE MARLY LAYERS, LOTS OF VEGETATION ON THIS SLOPE. FACE IS
WEATHERED TO LOOK LIKE CLAYEY GRAVEL/COBBLES WITH OCC.
RESISTANT BEDS RETAINING ROCK STRUCTURE. DEBRIS: GRAVEL TO 2'
BOULDER NOT VERY MUCH THOUGH

Date: 5/12/95
Page 1 of 7
Code I10-7

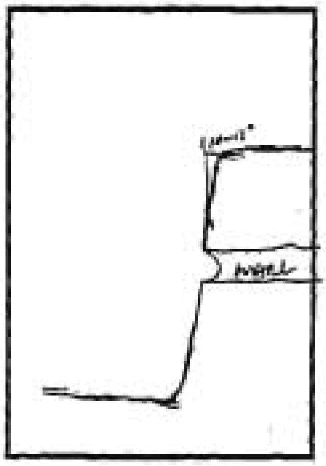
TxDOT Rock Mass Field Description

Glen Rose Formation

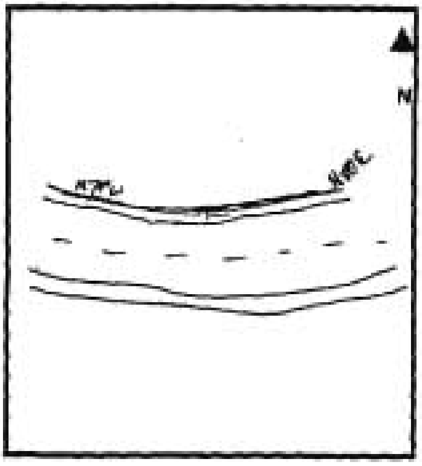
Location: I-10 W OF CYPRESS CREEK (3-5 mi EA of KERRVILLE) WEST BOUND SIDE

TxDOT District: SA

Elev. (ft)



Profile Sketch



Plan Sketch

General Exposure Description

Dimensions and Orientation:

Total Height (ft): 55'

Lateral Extent (ft): 2M + 415 + 60'

~~Benches~~: Height Width

L1 ______

L2 ______

L3 ______

Face Orientation: Strike/dip: N70°W on to N85°E, 10°-12° (98°-88°)

Catchment Description: SHALLOW GRASSED DITCH, FACE 30' FROM EOP

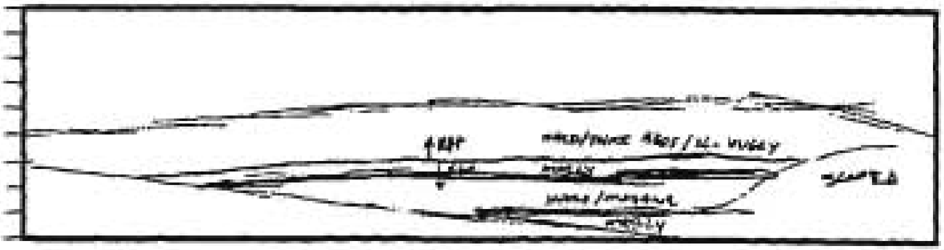
Artificial Support: NONE

Method of Excavation (incl. effects): BLAST

Age of Exposure: ______

Vegetation Effects: SOME SHRUB GROWTH OUT OF MARLY BEDS / SEAMS

Elev. (ft)



Elevation (ft) looking ___

TxDOT Rock Mass Field Description
Glen Rose Formation

Summary of Engineering Geologic Data

Joint Description Summary

Set #	Strike	Dip	Roughness	Separation/ Filling	Persistence	Weathering	Remarks

Other Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks

Occasional Random Joints? YES N 70° W, 90° DIP CONFINED TO UPPER CRYSTALLINE/SLIGHTLY [illegible] VUGGY BED (KET)

Bedding Description: 1-4' MARL BED @ MID HT & MIX AT PORTION, OTHERWISE HARD, SOME CRYSTALLINE, SLIGHTLY VUGGY BEDS THICK TO MASSIVE W/ OCC MARL (THIN <1') BEDS

Weathering/Erosion: MARL LAYER HAS ERODED UP TO 2' FROM FACE OTHERWISE JUST SURFACE DISCOLORATION

Form of Slope Failure/Degradation: VERY MINOR RAVELLING/SPALLING, SOME BLOCK FALL HAS OCCURRED IN HARD BED ABOVE MARL (NOT RECENT)

Debris: OCC. 6" - 1' BLOCK OTHERWISE JUST TYPICAL SMALL TALUS AT BASE

Maintenance Record:

Available Geotechnical Data:

TxDOT Rock Mass Field Description

Glen Rose Formation

Code I-10-4

Scanline Descriptions

Horizontal Scanline Number: ____
Horizontal Location (locate on sketch): ____________________
Height above base of cut (ft): ____
If w/in one layer, layer thickness: ______
Length of scanline (ft): ________
Strike of scanline (if different from face): ______________________________

0+00 0+50 1+00

Scanline Sketch (include seepage locations)

Debris Description

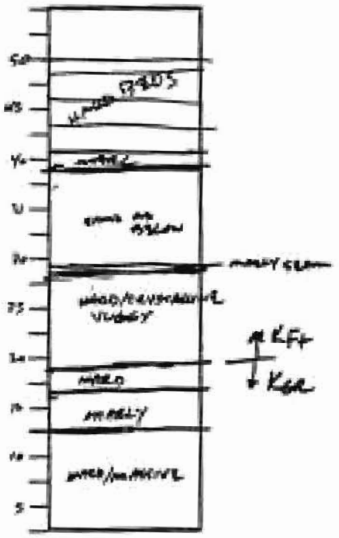
obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Condition
			+/-20	20-45	45-60	R/L	+/-20	20-45	45-60	R/L		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												

Set	Apparent spacing (#/scan length)	True Spacing (#/scan length)
1		
2		
3		
4		
5		

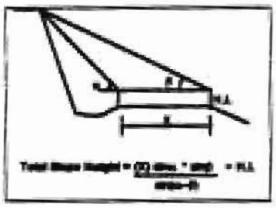
TxDOT Rock Mass Field Description
Glen Rose Formation

Scanline Descriptions

Vertical Scanline Number: 1
Scanline Location (show on sketch): MID CUT / MAX HT
Height of Scanline (ft): 50
Lrength of Scanline(ft): 1'



Scanline Sketch



Fracture frequency: ______
Est. RQD: 75 - 90

Scanline Information:

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Cond'n
			+/-20	20-45	45-60	R/L	+/-20	20-45	45-60	R/L		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												

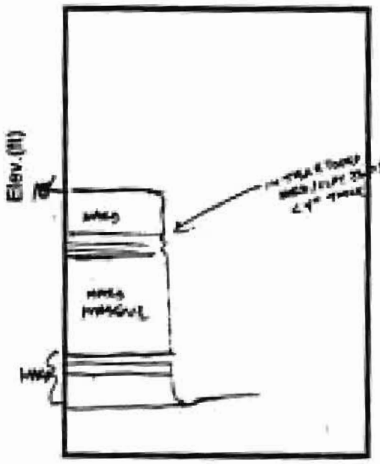
Date: 6/3/95
Page 1 of 4
Code I-10-7

TxDOT Rock Mass Field Description

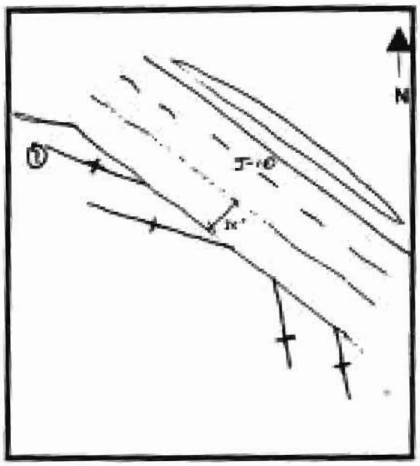
Formation: FT. TERRETT

Location: I-10 1 MILE WEST OF FM 783 NEAR KERRVILLE

TxDOT District: SAN ANTONIO



Profile Sketch



Plan Sketch

General Exposure Description

Dimensions and Orientation:

Total Height (ft): 18'

Lateral Extent (ft): 600'

Benches: Height Width

L1

L2

L3

Face Orientation: Strike/dip: N 60° W / 85° NE

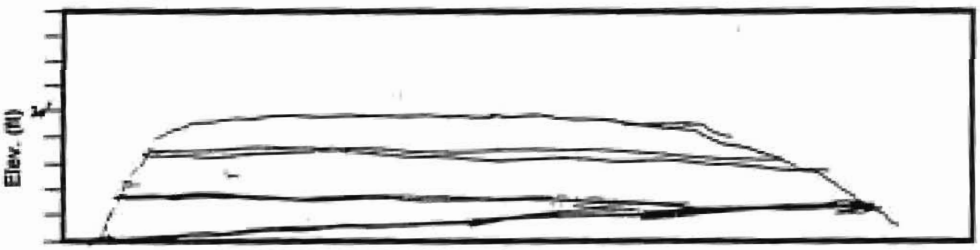
Catchment Description: SHALLOW DITCH, SET BACK 25' FROM TOP

Artificial Support: NONE

Method of Excavation (incl. effects): BLAST NONE

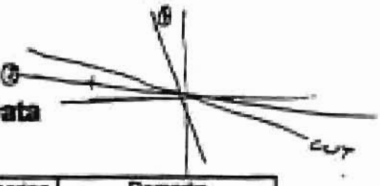
Age of Exposure:

Vegetation Effects: 3



Elevation (ft) looking SW

TxDOT Rock Mass Field Description



Summary of Engineering Geologic Data

Joint Description Summary

Set #	Strike	Dip	Roughness	Separation/ Filling	Persistence	Weathering	Remarks
1	N 70° W	90	ROUGH/PLANAR	TIGHT-10mm	P	II - III	SOME OR CLAY/SILT FILLING
2	N 30° W	90	R/U	TIGHT - 2"	P	Ia - Ib	NO FILLING

Other Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks

Occasional Random Joints? YES, 3 JTS NEAR EAST END NEARLY 60° DIP ⊥ STRIKE TO SLOPE (II THI THI IIII)

Bedding Description: HARD CRYSTALLINE BEDS, (1'-2' THICK LOWER 4' OF CUT; 1 MASSIVE BED, THIN CLAYEY BEDS ABOVE MIXED W/HARD BEDS (6"-12"). FOLLOWED BY 6'-7' THICK HARD BED ON TOP

Weathering/Erosion: DISCOLORATION, MINOR EROSION OF CLAYEY BEDS NEAR TOP OF CUT <1' OF RETREAT

Form of Slope Failure/Degradation: NONE

Debris: NONE

Maintenance Record:

Available Geotechnical Data:

TxDOT Rock Mass Field Description

Scanline Descriptions

Horizontal Scanline Number: 1
Horizontal Location (locate on sketch): WHOLE CUT
Height above base of cut (ft): 6'
If w/in one layer, layer thickness: ______
Length of scanline (ft): ENTIRE CUT (600')
Strike of scanline (if different from face): ______

0+00 0+50 1+00

Scanline Sketch (include seepage locations)

Debris Description

obs #	Sta.	Set	Strike w/r to exposure +/-20	20-45	45-90	R/L	Dip w/r to exposure +/-20	20-45	45-90	R/L	Persist.	Condition
1		1	X			L	X			N/A	P	[illegible] to 2"/R, U/I, -II/N, Fill
2		2	X			R	X			N/A	P	T/T to [illegible]/R/Plan [illegible]/I-II/[illegible]
3												
4												
5												
6												
7												
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9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												

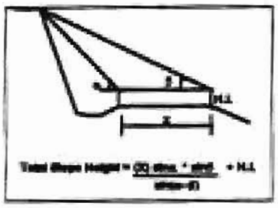
Set	Apparent spacing (#/scan length)	True Spacing (#/scan length)
1	9/600' = 67'	12'
2	12/600' = 50'	38'
3		
4		
5		

Code I-10-7

TxDOT Rock Mass Field Description

Scanline Descriptions

Vertical Scanline Number: ________
Scanline Location (show on sketch): ________
Height of Scanline (ft): ________
Length of Scanline(ft): ________



Scanline Sketch

Photo Listing

No.	Description
12	JOINTS
13	JOINTS
14	PANORAMIC LKG SE.

Samples Taken: NONE

BST RQD
75-85

Scanline Information:

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Cond'n
			+/-20	20-45	45-90	R/L	+/-20	20-45	45-90	R/L		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

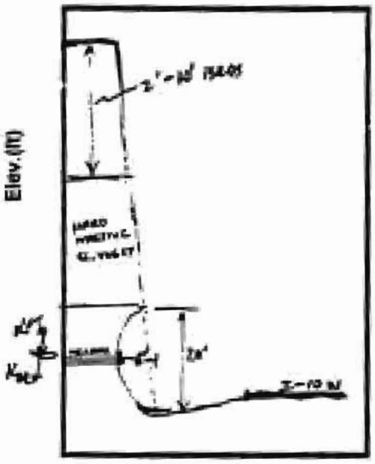
TxDOT Rock Mass Field Description

Formation: FT. TERRELL OVER GLEN ROSE

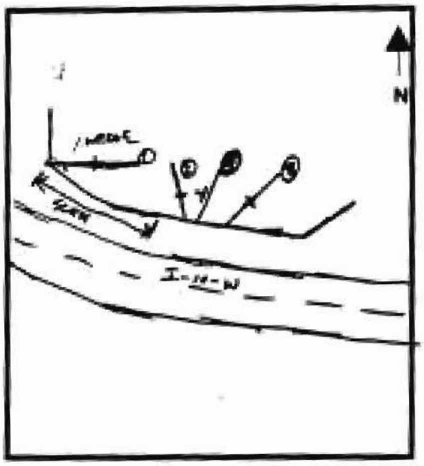
Location: I-10, JUST EAST OF FM 1338

N. WEST OF KERRVILLE

TxDOT District: SAN ANTONIO



Profile Sketch



Plan Sketch

General Exposure Description

Dimensions and Orientation:

Total Height (ft): 80'

Lateral Extent (ft): 236 × 4.35 = 1025'

~~Benches:~~ Height Width

L1

L2

L3

Face Orientation: Strike/dip: / 80°

Catchment Description: SHALLOW DITCH / 40 FT. SET BACK FROM EOP

Artificial Support: NONE

Method of Excavation (incl. effects): BLAST, NONE

Age of Exposure:

Vegetation Effects: NONE

Elev. (ft)

Elevation (ft) looking NW

DOT Rock Mass Field Description

Summary of Engineering Geologic Data

SPACING #/SCAN

...t Description Summary

...et #	Strike	Dip	Roughness	Separation/ Filling	Persistence	Weathering	Remarks	
1	DUE EAST	90°	R/UND	TITE	P in KET	Ia		6
2	N 38° W	90°	R/PLANAR	TITE	BC	Ia-Ib	CONFINED TO MASSIVE KET	2
3	N 50° E	60° NW	R/UND	TITE	BC	Ia-Ib	" " "	4
4	N 20° E	70°	R/P	TITE	BC	Ia-Ib	" " "	1

...er Structural Features

...ure	Strike	Dip	Condition	Persistence	Remarks

...sional Random Joints? JT. OR TENSILE CRACK ESSENTIAL PARALLEL TO CUT BEHIND FACE OPEN 6" AT TOP [illegible] TO TITE 10' BELOW

...ding Description: From 0'-10' TYPICAL KGR (2'-3' BET. HARD/MARLY), FOLLOWED BY 6' NODULAR SOFTER LS, FOLLOWED BY 35'-40' MASSIVE BED (HARD LKG, VUGGY) FOLLOWED ON TOP BY 2'-10' BEDS

...thering/Erosion: LOWER NODULAR LAYER OF K_{ET} + UPPER MARLY KGR HAVE RETREATED UP TO 6' BEHIND FACE. JOINT DISCOLORATION OTHERWISE

...of Slope Failure/Degradation: RAVELLING / BLOCK FALL IN ELEV RACE AND 1ST GRAY NODULAR BED AT FT. TERRACE. WEDGE FAILURE @ WEST END AT TURN IN CUT (SEE SKETCH, PHOTOS). OCC BLOCK/WEDGE IN MASSIVE KET

...is: GRAVEL TO 6-FT BOULDER SIZE

...tenance Record:

...able Geotechnical Data:

TxDOT Rock Mass Field Description

Scanline Descriptions

Horizontal Scanline Number: 1
Horizontal Location (locate on sketch): ~~[illegible]~~ W. END STARTING @ END IN CUT GOING EAST
Height above base of cut (ft): 20'-25'
If w/in one layer, layer thickness: ______
Length of scanline (ft): 235'
Strike of scanline (if different from face): SAME

0+00 0+50 1+00

Scanline Sketch (include seepage locations)

Debris Description

obs #	Sta.	Set	Strike w/r to exposure +/-20	20-45	45-90	R/L	Dip w/r to exposure +/-20	20-45	45-90	R/L	Persist.	Condition
1	—	1	X			R	X			L	P in KET	TITI to 1cm/R/U/I-II/DRY/NO FILL
2	—	2			X	L	X			N/A	BC	TITI/R P/I-II/DRY/NO FILL
3	—	3			X	L	X			N/A	BC	" " " " " "
4	—	4			X	R	X			N/A	BC	" " " " " "
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												

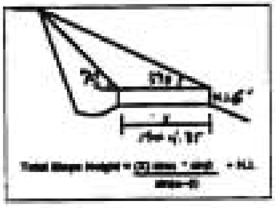
Set	Apparent spacing (ft/scan length)	True Spacing (ft/scan length)	
1	39'	7'	卌 I
2	118'	102'	II
3	59'	45'	IIII
4	235'	230'	I
5			

Page 4 of 4
Code I-10-B

TxDOT Rock Mass Field Description

Scanline Descriptions

Vertical Scanline Number: ________
Scanline Location (show on sketch): ________
Height of Scanline (ft): ________
Length of Scanline(ft): ________



+ 3' DITCH

Scanline Sketch

Photo Listing

No.	Description
15	CANTILEVER
16	OPEN JT OR TENSILE CRACK BEHIND FACE — NEAR EAST END
17	WEATHERING PROFILE LKG
18	SEEPAGE AT [illegible]
19	BLOCK / [illegible] IN [illegible] LOOKING [illegible]
20	VERTICAL VIEW LKG N
21	DEBRIS
22	[illegible] FAILURE IN [illegible]
23	
24	CLOSE UP OF OVERHANG
25	WEDGE ~~[illegible]~~ FAILURE @ [illegible] END

1, 2 PANORAMIC LKG S

Samples Taken:
NONE

Scanline Information:

obs #	Sta.	Set	Strike w/r to exposure +/-20	20-45	45-90	R/L	Dip w/r to exposure +/-20	20-45	45-90	R/L	Persist.	Cond'n
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

Date: 6/13
Page 1 of 4
Code I-10-9

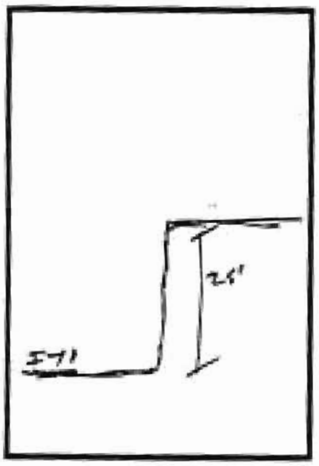
TxDOT Rock Mass Field Description

Formation: SEGOVIA (EDWARDS)

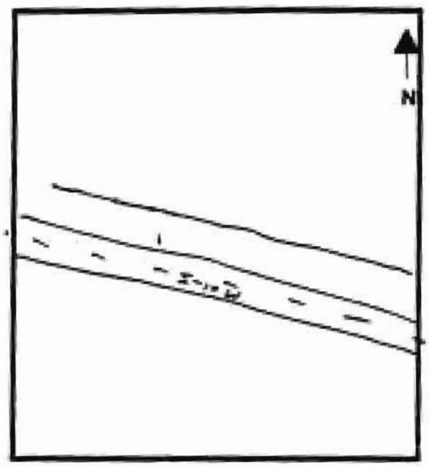
Location: I-10 IN GILLESPIE COUNTY
MILE MARKER 495

TxDOT District: SAN ANTONIO

Elev. (ft)



Profile Sketch



Plan Sketch

General Exposure Description

Dimensions and Orientation:

Total Height (ft): ~~30'~~ 25'
Lateral Extent (ft): 1200'
~~Benches:~~ Height Width
L1
L2
L3

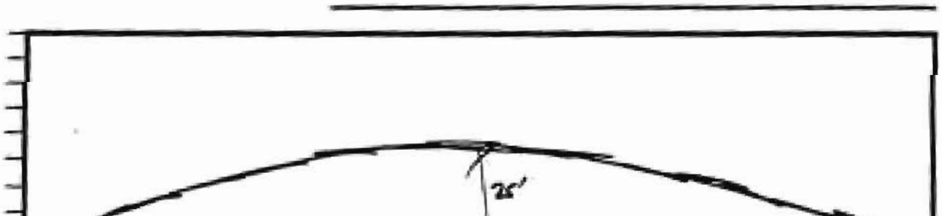
Face Orientation: Strike/dip: N 75° W, 90°
Catchment Description: NARL, 5%
Artificial Support: NONE

Method of Excavation (incl. effects): BLASTED, SHOT HOLES OBSERVED

Age of Exposure:

Vegetation Effects: NONE

Elev. (ft)



Elevation (ft) looking ___

TxDOT Rock Mass Field Description

Summary of Engineering Geologic Data

Joint Description Summary

Set #	Strike	Dip	Roughness	Separation/ Filling	Persistence	Weathering	Remarks
			N/A				

Other Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks

OCC. VOIDS IN FACE

Occasional Random Joints? N/A

Bedding Description: NO RESEMBLANCE OF BEDDING, ENTIRE CUT IS CALCAREOUS BRECCIA (LOOKS LIKE LS. CONGLOMERATE)

GENERALLY HARD CRYSTALLINE PIECES W/ SOFTER MATRIX. OCCASIONAL POCKETS OF CALCAREOUS SILT W/ SM LS FRAGS

Weathering/Erosion: NONE EXCEPT FOR EROSION OF OCC. SOFT POCKETS

Form of Slope Failure/Degradation: MINOR SPALLING

Debris: ~~[illegible]~~ V. LITTLE (GRAVEL TO 1' BOULDER SIZE)

Maintenance Record:

Available Geotechnical Data:

TxDOT Rock Mass Field Description

Scanline Descriptions

Horizontal Scanline Number: ____
Horizontal Location (locate on sketch): ____________________
Height above base of cut (ft): ____
If w/in one layer, layer thickness: ______
Length of scanline (ft): ________
Strike of scanline (if different from face): ______________________________

0+00 0+50 1+00

Scanline Sketch (include seepage locations)

Debris Description

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Condition
			+/-20	20-45	45-60	R/L	+/-20	20-45	45-60	R/L		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												

Set	Apparent spacing (#/scan length)	True Spacing (#/scan length)
1		
2		
3		
4		
5		

Page 4 of 4
Code E10-9

TxDOT Rock Mass Field Description

Scanline Descriptions

Vertical Scanline Number: ________
Scanline Location (show on sketch): ____________________
Height of Scanline (ft): ________
Length of Scanline(ft): ________

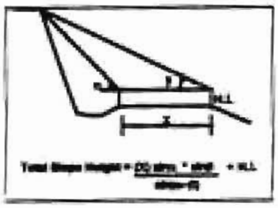


Photo Listing

No.	Description
8-10	MISC
11	BANDED SOFT POCKETS
12	> I-10 @ FM 477 IH KERR CO.
13	PILLING/COLLAPSE

Scanline Sketch
RST
RQD = < 20

Samples Taken: ____________________

Scanline Information:

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Cond'n
			+/-20	20-45	45-90	R/L	+/-20	20-45	45-90	R/L		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

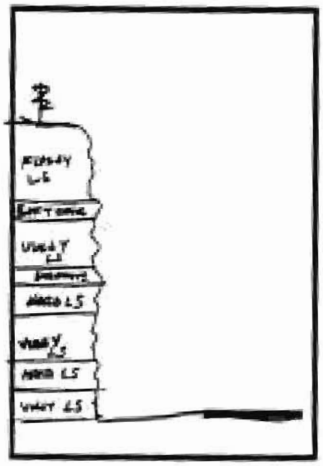
Date: 6/14/95
Page 1 of 4
Code 41-1

TxDOT Rock Mass Field Description

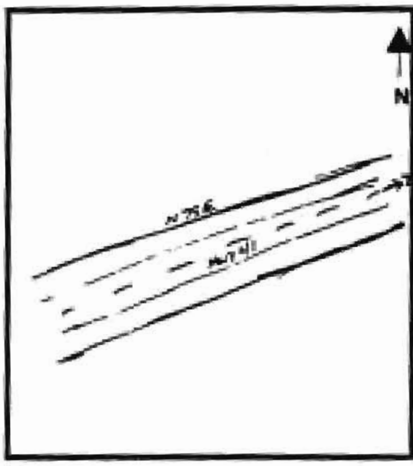
Formation: Fort Terret (Edwards) (Upper)

Location: SH.41 & S.H.27 West of Kerrville

TxDOT District: San Antonio



Profile Sketch



Plan Sketch

General Exposure Description

Dimensions and Orientation:

Total Height (ft): 34'-35'±

Lateral Extent (ft): 732 W of 41 = 1000'

Benches: Height Width

L1

L2

L3

Face Orientation: Strike/dip: N75°E, essentially vertical but rough

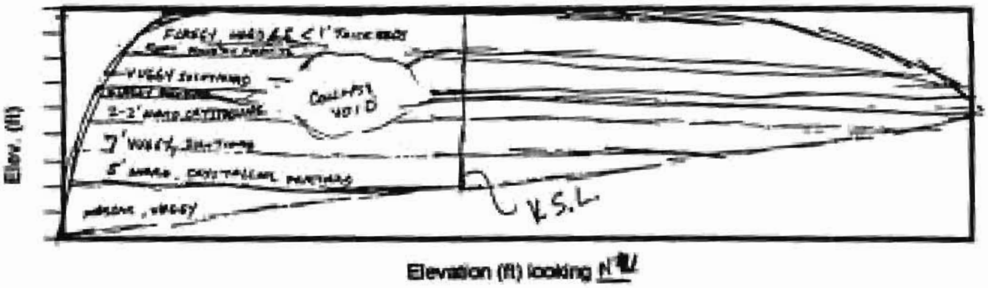
Catchment Description: None. Set back 30' from EOP

Artificial Support: None

Method of Excavation (incl. effects): Mass blast or mechanical, no shot holes

Age of Exposure:

Vegetation Effects: None



Elevation (ft) looking NW

TxDOT Rock Mass Field Description

Summary of Engineering Geologic Data

NO JOINTING → OTHER THAN BED CONFINED FRACTURING

Joint Description Summary

Set #	Strike	Dip	Roughness	Separation/ Filling	Persistence	Weathering	Remarks

Other Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks

Occasional Random Joints? BED CONFINED HIGH FREQUENCY FRACTURING / JOINTING ONLY IN HARD ~~[illegible]~~ CRYSTALLINE BEDS AND DOLOMITE NOT IN VUGGY ZONES

Bedding Description: HARD CRYS. LS, VUGGY BEDS, DOLOMITE. AS SHOWN ON VERTICAL S.L. AND ELEV. SKETCH, THICKNESS 1' TO 8' AVG 2-3'

Weathering/Erosion: SLIGHT EROSION OF VUGGY ZONES AND SOFT DOLOMITE ABOVE SOLUTION COLLAPSE

Form of Slope Failure/Degradation: FALL ~~[illegible]~~ OUT OF COLLAPSE VOID INVOLVES SMALL BLOCKS FROM FRACTURED BEDS, SOME LOOSE BLOCKS OBSERVED. BLOCKS APPEAR TO RANGE FROM INCHES TO 2' (AVG 1').

Debris: OCC. COBBLE TO 8" ROCK

Maintenance Record:

Available Geotechnical Data:

TxDOT Rock Mass Field Description

Scanline Descriptions

NONE CONDUCTED

Horizontal Scanline Number: ____
Horizontal Location (locate on sketch): ____________
Height above base of cut (ft): ____
If w/in one layer, layer thickness: ____
Length of scanline (ft): ____
Strike of scanline (if different from face): ____________

0+00 0+50 1+00

Scanline Sketch (include seepage locations)

Debris Description

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Condition
			+/-20	20-45	45-90	R/L	+/-20	20-45	45-90	R/L		
1												
2												
3												
4												
5												
6												
7												
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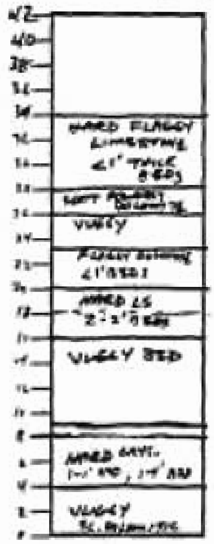
15												
16												
17												
18												
19												
20												
21												
22												

Set	Apparent spacing (ft/scan length)	True Spacing (ft/scan length)
1		
2		
3		
4		
5		

TxDOT Rock Mass Field Description

Scanline Descriptions

Vertical Scanline Number: 1
Scanline Location (show on sketch): RIGHT OF SOLUTION COLLAPSE VOB
Height of Scanline (ft): ________
Length of Scanline(ft): ________



Scanline Sketch

EST 70 - 75 RQD

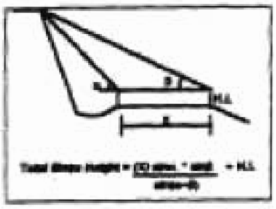


Photo Listing

No.	Description
[illegible]	
10-16	
17	FM 2828 [illegible] W. OF SAMOSLA CREEK / KAR, SOLUTION WEATHERING / EROSION

Samples Taken: NON

Scanline Information:

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Cond'n
			+/-20	20-45	45-90	R/L	+/-20	20-45	45-90	R/L		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

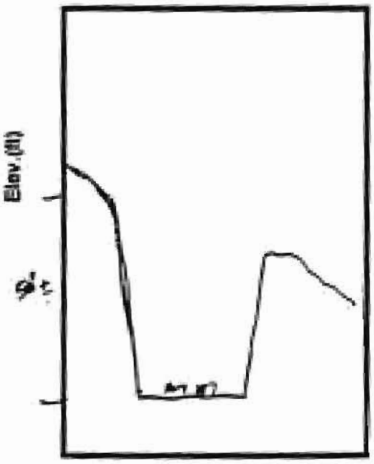
Date: 6/3/05
Page 1 of 4
Code 187-1

TxDOT Rock Mass Field Description

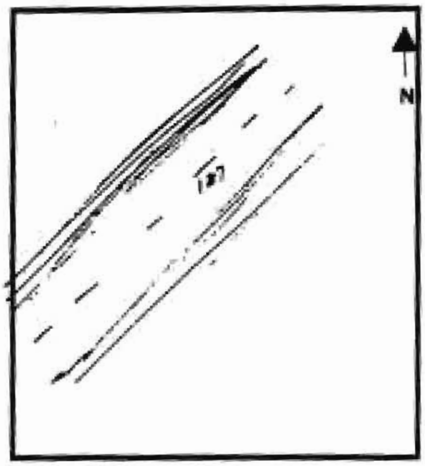
Formation: FT. TERRETT

Location: ST. HWY 187 N. OF LOST MAPLES ST. PARK

TxDOT District: SAN ANTONIO



Profile Sketch



Plan Sketch

General Exposure Description

Dimensions and Orientation:

Total Height (ft): 50'

Lateral Extent (ft): 1/2 MILE = 2600'

~~Benches: Height Width~~

~~L1~~ ______

L2 ______

L3 ______

Face Orientation: Strike/dip: N 40°E, 75°

Catchment Description: NONE; ~~SLOPE~~ ~~[illegible]~~ PAVT GOES RIGHT UP TO CUT

Artificial Support: NONE

Method of Excavation (incl. effects): BLAST, NONE

Age of Exposure: ______

Vegetation Effects: OCC. SM CLUM, BRUSH GROWING OUT OF SOIL POCKETS IN VOIDS

Elev. (ft)

Elevation (ft) looking /

TxDOT Rock Mass Field Description

Summary of Engineering Geologic Data

Joint Description Summary

Set #	Strike	Dip	Roughness	Separation/ Filling	Persistence	Weathering	Remarks
JOINTS							

Other Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks

Occasional Random Joints? NONE OBSERVED

Bedding Description: MASSIVE, HARD, CRYSTALLINE, W/CHERT NODULES, VUGS (SOME SOIL FILLED. 3-2' BEDS INTERBEDDED WITH MASSIVE BEDS

Weathering/Erosion: DISCOLORATION

Form of Slope Failure/Degradation: VERY VERY MINOR SPALLING

Debris: OCC 2"-4" LS FRAGS

Maintenance Record:

Available Geotechnical Data:

TxDOT Rock Mass Field Description

Scanline Descriptions

NOT PERFORMED

Horizontal Scanline Number: ____
Horizontal Location (locate on sketch): ____________________
Height above base of cut (ft): _____
If w/in one layer, layer thickness: ________
Length of scanline (ft): __________
Strike of scanline (if different from face): ______________________________

0+00 0+50 1+00

Scanline Sketch (include seepage locations)

Debris Description

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Condition
			+/-20	20-45	45-60	Rt.	+/-20	20-45	45-60	Rt.		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												

Set	Apparent spacing (ft/scan length)	True Spacing (ft/scan length)
1		
2		
3		
4		
5		

Code 187-7

TxDOT Rock Mass Field Description

Scanline Descriptions

Vertical Scanline Number: ________
Scanline Location (show on sketch): ________
Height of Scanline (ft): ________
Length of Scanline(ft): ________

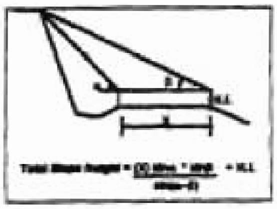


Photo Listing

No.	Description
14	PAN LKG E
15	PAN LKG W
16	PAN LKG W

Scanline Sketch

BST RQD
85-100

Samples Taken: ________

Scanline Information:

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Cond'n
			+/-20	20-45	45-90	R/L	+/-20	20-45	45-90	R/L		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

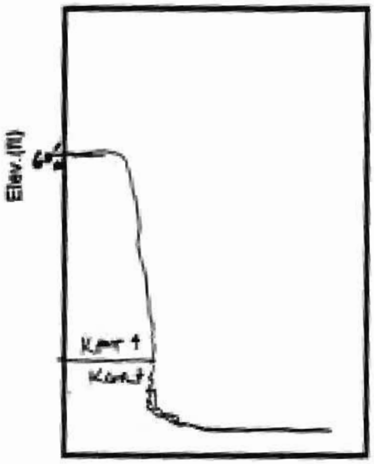
Date: 6/3/95 ✓
Page 1 of 4
Code 337-1

TxDOT Rock Mass Field Description

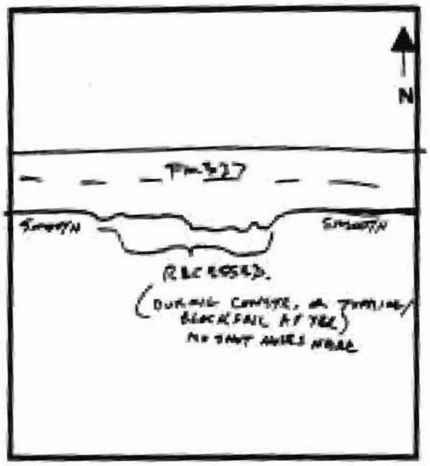
Formation: Kpt / Kgn

Location: FM 337 JUST EAST OF MILL CREEK ROAD R.M. 492

TxDOT District: SAN ANTONIO



Profile Sketch



Plan Sketch

General Exposure Description

Dimensions and Orientation:

Total Height (ft): 60'
Lateral Extent (ft): 150 x 4.35 = 650'
~~Benches:~~ ~~Height~~ Width
L1
L2
L3
Face Orientation: Strike/dip: DUE WEST / 75°
Catchment Description: NONE, CURBS UP TO PVMT
Artificial Support: NONE

Method of Excavation (incl. effects): BLAST

Age of Exposure:

Vegetation Effects: OCC. SAP, WEEDS IN GLOW RISE

Elevation (ft) looking SOUTH

TxDOT Rock Mass Field Description

Summary of Engineering Geologic Data

Joint Description Summary

Set #	Strike	Dip	Roughness	Separation/ Filling	Persistence	Weathering	Remarks
1	N65°E	75°	V. ROUGH/UND	UP TO 1 FT.	THROUGH GOING	II	FILLED IN SOME PLACES W/BRECCIA
				TITE @ TOP			
				OF SLOPE			
2	N 40°W	90°	V. ROUGH/UND	TITE TO 2"	THROUGH GOING	II	SILT & GRAVEL WHERE OPEN

Other Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks

Occasional Random Joints? YES VERTICAL BC FRACTURES/JOINTS IN Kgr

Bedding Description: MASSIVE, NODULAR, VUGGY IN Ket, 2'-4' ALTERNATING BEDS IN Kgr

Weathering/Erosion: SEVERE EROSION/SLUMPING IN Kgr. DISCOLORATION IN Ket. SOME FRESH TAN SURFACES INDICATE SPORADIC RAVELLING/MINOR ROCKFALL (2'-3' BLOCKS)

Form of Slope Failure/Degradation: ~~SE~~ MINOR RAVELLING IN Ket, SEVERE RAVELLING, BLOCK FALL IN Kgr. POTENTIAL FOR LARGE TOPPLING IN Ket @ IT SET 1 AREAS

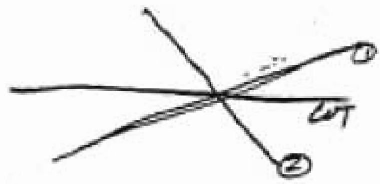
Debris: GRAVEL TO 2' BOULDERS

Maintenance Record:

Available Geotechnical Data:

TxDOT Rock Mass Field Description

Scanline Descriptions



Horizontal Scanline Number: 1
Horizontal Location (locate on sketch): ______
Height above base of cut (ft): 10'
If w/in one layer, layer thickness: ______
Length of scanline (ft): ENTIRE CUT 650'
Strike of scanline (if different from face): ______

0+00 0+50 1+00

Scanline Sketch (include seepage locations)

Debris Description

obs #	Sta.	Set	Strike w/r to exposure +/-20	20-45	45-90	R/L	Dip w/r to exposure +/-20	20-45	45-90	R/L	Persist.	Condition
1		1		X		L	X			R	P	VR/[illegible] 1" [illegible] /DRY/ II [illegible]
2		2		X		R	X			[illegible]	P	VR/[illegible]/[illegible] 2"/DRY/ II
3												
4												
5												
6												
7												
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18												
19												
20												
21												
22												

Set	Apparent spacing (#/scan length)	True Spacing (#/scan length)	
1	72'	41'	𝍸 IIII
2	130'	113'	𝍸
3			
4			
5			

TxDOT Rock Mass Field Description

Scanline Descriptions

Vertical Scanline Number: ________
Scanline Location (show on sketch): ________
Height of Scanline (ft): ________
Length of Scanline(ft): ________

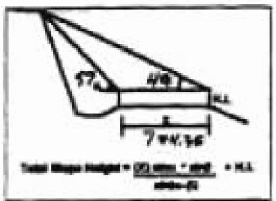


Photo Listing

No.	Description
17	
18	
19	
20	
21	

Scanline Sketch

BST RAD
K_{FT} = 80-100
K_{GR} = 40-60

Samples Taken: None

Scanline Information:

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Cond'n
			+/-20	20-45	45-60	R/L	+/-20	20-45	45-60	R/L		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

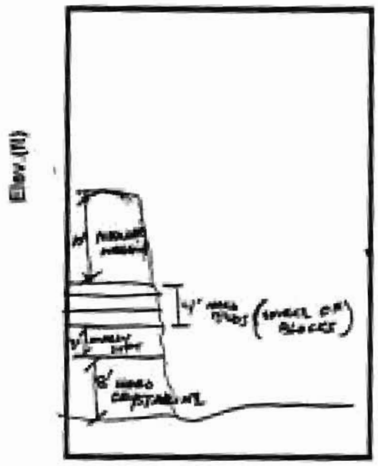
Date: 6/3/95 ✓
Page 1 of 4
Code 337-2

TxDOT Rock Mass Field Description

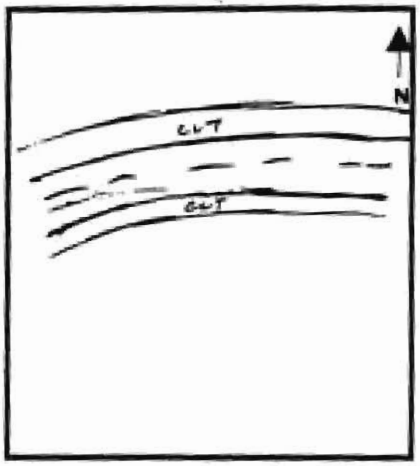
Formation: [illegible]

Location: FM 337 @ TOP OF HILL WEST OF [illegible]

TxDOT District: SAN ANTONIO



Profile Sketch



Plan Sketch

General Exposure Description

Dimensions and Orientation:

Total Height (ft): 25' ±

Lateral Extent (ft): 145 × 4.35' = 630'

Benches: Height Width

L1 ______

L2 ______

L3 ______

Face Orientation: Strike/dip: N 70°E [illegible] - N90°E, VARIES 75° - 70°

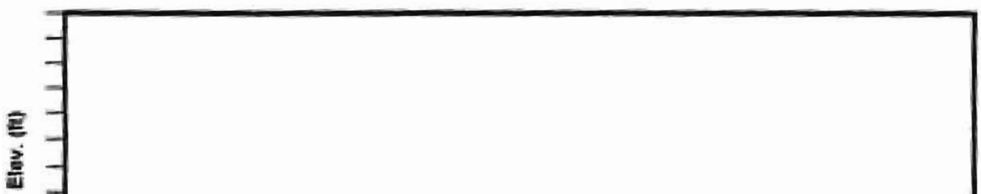
Catchment Description: SHALLOW DITCH, SET BACK 10' FROM EOP

Artificial Support: NONE

Method of Excavation (incl. effects): BLAST, SHOT HOLES APPEAR FRESH, NOT WEATHERED DK-GRAY LIKE SURROUNDING ROCK

Age of Exposure: ______

Vegetation Effects: NONE



Elevation (ft) looking ___

TxDOT Rock Mass Field Description

Summary of Engineering Geologic Data

Joint Description Summary

Set #	Strike	Dip	Roughness	Separation/ Filling	Persistence	Weathering	Remarks

Other Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks

Occasional Random Joints? YES, CONFINED TO LOWER 8' THICK CRYSTALLINE BED, N60°E, 90° ± 5 ENTIRE LENGTH OF CUT (27' TYPICAL SPACING)

Bedding Description: B → TOP: 8' HARD MASSIVE BED, 3' MARLY, NODULAR BED, 4 - 6"-2' BEDS, 10' NODULAR MASSIVE BED. MIDDLE HARD BEDS ARE MAINLY FRACTURED INTO 3" → 2' BLOCKS.

Weathering/Erosion: DISCOLORATION, SLIGHT EROSION OF MARLY BED

Form of Slope Failure/Degradation: BLOCK FALL FROM MIDDLE HARD BEDS, MINOR RAVELLING SOME SM. BLOCKS (1') FROM LOWER MASSIVE BED

Debris: GRAVEL TO 1' BOULDER SIZE TALUS PUSHED AGAINST TOE. APPEARS TO HAVE BEEN CLEARED RECENTLY

Maintenance Record:

Available Geotechnical Data:

TxDOT Rock Mass Field Description

Scanline Descriptions

Horizontal Scanline Number: ____
Horizontal Location (locate on sketch): ____________________
Height above base of cut (ft): _____
If w/in one layer, layer thickness: ________
Length of scanline (ft): ________
Strike of scanline (if different from face): ____________________

NO SCANLINE. NO MAJOR JOINTS HOWEVER, LOWER MASSIVE BED IS FRACTURED AND MIDDLE HARD BEDS ARE HIGHLY FRACTURED (LOWER BOLD DURABLE)

0+00 0+50 1+00

Scanline Sketch (include seepage locations)

Debris Description

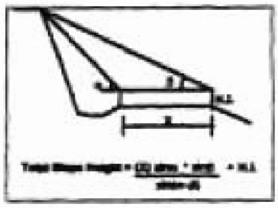
obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Condition
			+/-20	20-45	45-90	R/L	+/-20	20-45	45-90	R/L		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												

Set	Apparent spacing (#/scan length)	True Spacing (#/scan length)
1		
2		
3		
4		
5		

TxDOT Rock Mass Field Description

Scanline Descriptions

Vertical Scanline Number: ________
Scanline Location (show on sketch): ____________________
Height of Scanline (ft): ________
Length of Scanline(ft): ________



Scanline Sketch

EST. RQD
75-80

Photo Listing

No.	Description
1	
2	VERTICAL PROFILE
3	

Samples Taken: NONE

Scanline Information:

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Cond'n
			+/-20	20-45	45-90	R/L	+/-20	20-45	45-90	R/L		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

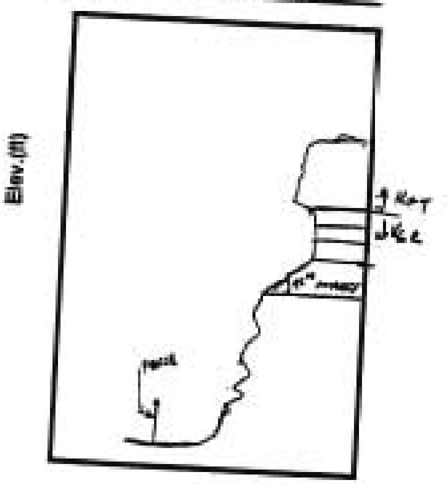
TxDOT Rock Mass Field Description

Date: 6/14
Page 1 of 4
Code 470-1

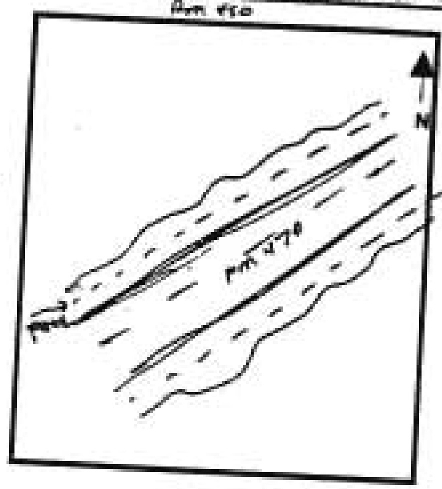
Formation: Upper Glen Rose

TxDOT District: San Antonio

Location: FM 470 Tarpley Pass
Btwn Bandera & Tarpley
Rm 460



Profile Sketch



Plan Sketch

General Exposure Description

Dimensions and Orientation:

Total Height (ft): 55 ±

Lateral Extent (ft): 20+04.33 − 30' = 975'

~~Benches~~: Height Width

L1

L2

L3

Face Orientation: Strike/dip: N 60°E, 80-90° varies

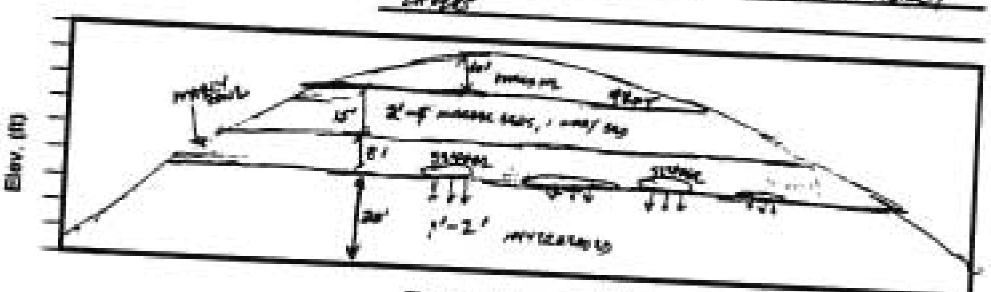
Catchment Description: 3' high chain link fence 8'-10' from toe

Artificial Support: None

Method of Excavation (incl. effects): ?

Age of Exposure:

Vegetation Effects: Degradation (?) in marly layer



Elevation (ft) looking NW

TxDOT Rock Mass Field Description

Summary of Engineering Geologic Data

Joint Description Summary

Set #	Strike	Dip	Roughness	Separation/ Filling	Persistence	Weathering	Remarks
		NONE		OBSERVED			

Other Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks

Occasional Random Joints? NONE OBSERVED IN GLEN ROSE. BC JOINTS (VERTICAL, ⊥ TO SLOPE, [illegible] < 1" OPENING OBSERVED IN KET (SEE PHOTO 21)

Bedding Description: INTERBEDDED HARD/SOFTER MARLY LAYERS IN GLEN ROSE. LOWER 20' THICKNESS IS 6"-2', CAN'T TELL IN THICK MARLY ZONE DUE TO EROSION, THEN 2'-4' TO KET WHICH LOOKS TO BE MASSIVE.

Weathering/Erosion: SEVERE EROSION OF MARLY ZONE AT MID SLOPE. MINOR EROSION LOWER 20'. MARLY ZONE HAS EROSION GULLEYS AND APPEARS SOIL LIKE. (1H:1V)

Form of Slope Failure/Degradation: BLOCK FALL & DEBRIS SLIDES DUE TO EROSION OF MARLY ZONE. RAVELLING IN LOWER 20'

Debris: LARGE TALUS PILES (CLAY - 2' BOULDER), SOME BLOCKS OBSERVED 6"-3'

Maintenance Record:

Available Geotechnical Data:

TxDOT Rock Mass Field Description

Scanline Descriptions

NOT PERFORMED

Horizontal Scanline Number: ____
Horizontal Location (locate on sketch): ____________
Height above base of cut (ft): ____
If w/in one layer, layer thickness: ______
Length of scanline (ft): ______
Strike of scanline (if different from face): ____________

NO JOINTS OBSERVED IN KGR ONLY IN OVERLYING KFT

0+00 0+50 1+00

Scanline Sketch (include seepage locations)

Debris Description

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Condition
			+/-20	20-45	45-90	R/L	+/-20	20-45	45-90	R/L		
1												
2												
3												
4												
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6												
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14												
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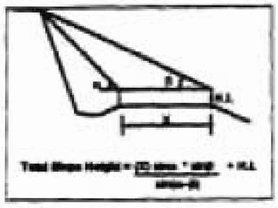
16												
17												
18												
19												
20												
21												
22												

Set	Apparent spacing (#/scan length)	True Spacing (#/scan length)
1		
2		
3		
4		
5		

TxDOT Rock Mass Field Description

Scanline Descriptions

Vertical Scanline Number: ________
Scanline Location (show on sketch): ________
Height of Scanline (ft): ________
Length of Scanline(ft): ________



Scanline Sketch

Photo Listing

No.	Description
18-21	
1	

Samples Taken: 2 SAMPLES OF MARL TAKEN (1 FROM WEATHERED SURFACE, 1 FROM FRESH MAT'L BACK FROM FACE.

Scanline Information:

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Cond'n
			+/-20	20-45	45-90	R/L	+/-20	20-45	45-90	R/L		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

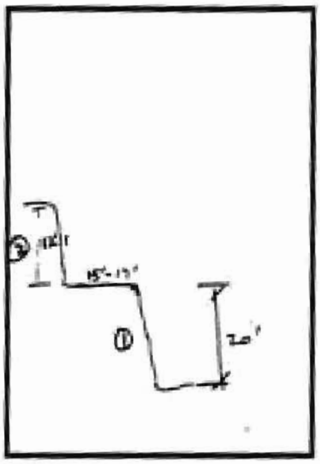
Date: 6/1
Page 1 of 4
Code 211-1

TxDOT Rock Mass Field Description

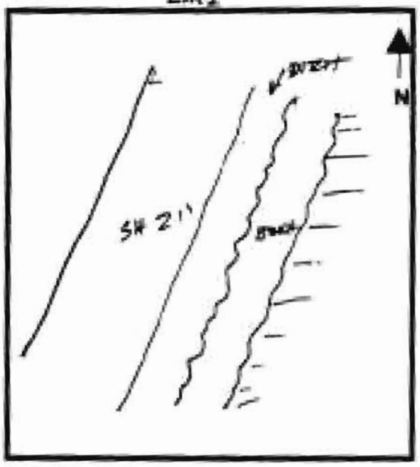
Formation: EDWARDS

Location: S.H. 211 N. OF FM 471 IN MEDINA CO. JUST SOUTH OF BEXAR CO. LINE

TxDOT District: SAN ANTONIO



Profile Sketch



Plan Sketch

General Exposure Description

Dimensions and Orientation:

Total Height (ft): 32'

Lateral Extent (ft): 0.2 miles = 1000'

Benches / Height Width

L1 20 15'-17'

L2 12

L3

Face Orientation: Strike/dip: N05°E, 16° LAY BACK (74° DIP)

Catchment Description: SHALLOW CONC. DITCH, 13' FROM TOE TO EOP (SHOULDER)

Artificial Support: NONE

Method of Excavation (incl. effects): BLAST BOTH SLOPES ON BENCH

Age of Exposure: 3 YR

Vegetation Effects: NONE

Elev. (ft)

Elevation (ft) looking S

TxDOT Rock Mass Field Description

Summary of Engineering Geologic Data

Joint Description Summary

Set #	Strike	Dip	Roughness	Separation/ Filling	Persistence	Weathering	Remarks
	NO	JOINTS					

Other Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks

Occasional Random Joints? NO JOINTS OTHER THAN BED FRACTURING

Bedding Description: HARD CRYSTALLINE / FOSSILIFEROUS BEDS, ALTERNATING W/ VUGGY BEDS W/ CLAY FILLING (SOME SOLUTION ([illegible]) VOIDS (2")

Weathering/Erosion: UPPER 5' BED OF TOP SLOPE IS WEATHERED W/ SOME SOIL APPEARANCE

Form of Slope Failure/Degradation: LOTS OF SMALL BLOCK FALL DUE TO HIGH FREQ. BED CONTAINED FRACTURING

Debris: GRAVEL → 2' LG. BLOCKS. JUDGING FROM SLOPE BLOCK SIZE [illegible] RANGE FROM <1" TO 3'; UNLIKELY TO HAVE BLOCKS LARGER THAN THIS DUE TO HIGH FREQ. FRACTURING

Maintenance Record: FENCED AFTER CONSTRUCTION DUE TO BLOCK FALL / RAVELLING. HAVE TO CLEAN DITCH / ROAD 1 TIME / YEAR

Available Geotechnical Data:

TxDOT Rock Mass Field Description

Scanline Descriptions

Horizontal Scanline Number: ____
Horizontal Location (locate on sketch): ____________________
Height above base of cut (ft): _____
If w/in one layer, layer thickness: ________
Length of scanline (ft): _________
Strike of scanline (if different from face): ______________________________

0+00 0+50 1+00

Scanline Sketch (include seepage locations)

Debris Description

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Condition
			+/-20	20-45	45-90	R/L	+/-20	20-45	45-90	R/L		
1												
2												
3												
4												
5												
6												
7												
8												
9												
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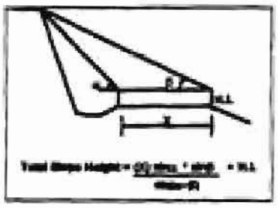
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												

Set	Apparent spacing (#/scan length)	True Spacing (#/scan length)
1		
2		
3		
4		
5		

TxDOT Rock Mass Field Description

Scanline Descriptions

Vertical Scanline Number: 1
Scanline Location (show on sketch): MID-SLOPE (LOWER SLOPE BENCH
Height of Scanline (ft):
Length of Scanline(ft): N/A



5' { 1" → 1' BEDS
LINEARLY FRACTURED/[illegible]
4' HARD CRYS. (2" - 2' BEDS)
3' VUGGY w/[illegible] [illegible] BENCH (LIMESTONE CHALKY ROCK)
6' VUGGY / HARD (EXTREMELY FRACTURED)
3.5' HARD (1980)
BDS 2' VUGGY w/[illegible] (1980)
5' HARD (1980)
4' HARD (1980)

Scanline Sketch

BEST RQD = 20-40

Photo Listing

No.	Description
11	TYPICAL HIGH FREQ. FRACTURING
12	FACE + DITCH
13	DEBRIS
14	FRACTURING
15	VERTICAL
16	BENCH

Samples Taken: NONE

Scanline Information:

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Cond'n
			+/-20	20-45	45-90	R/L	+/-20	20-45	45-90	R/L		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

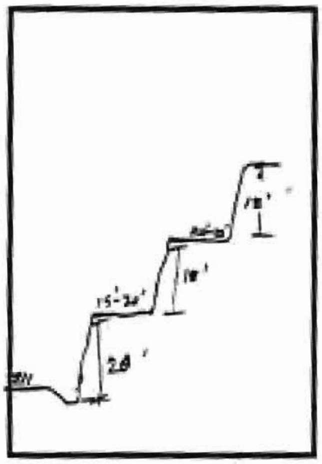
Date: 6/10/95
Page 1 of 4
Code 211-2

TxDOT Rock Mass Field Description

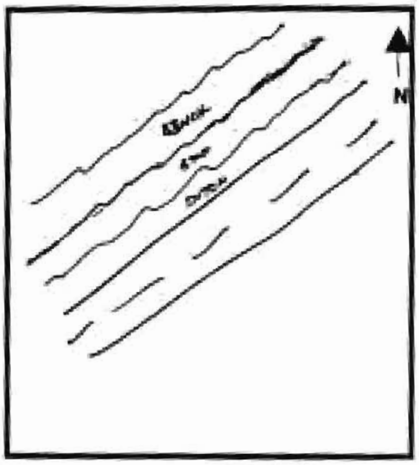
Formation: EDWARDS

Location: S.H. 211 (WEST SIDE) JUST N. OF BEXAR CO. LINE (HIGHER EL. THAN 211-1)

TxDOT District: SAN ANTONIO



Profile Sketch LKG SW



Plan Sketch

General Exposure Description

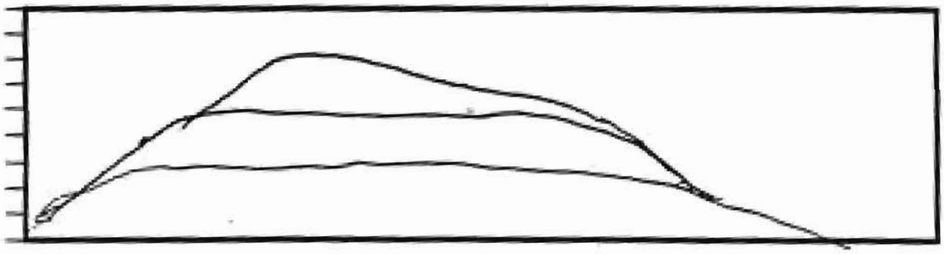
Dimensions and Orientation:

Total Height (ft): 56'
Lateral Extent (ft): .35 miles ±
Benches: 2 Height Width
L1 20 15-20
L2 18 20-25
L3 18

Face Orientation: Strike/dip: N55°E, 15° LAY BACK (75° DIP)
Catchment Description: STEEP DITCH, 20' FROM TOE TO EOP
Artificial Support: NONE

Method of Excavation (Incl. effects): BLAST: TOP FAIRLY SMOOTH, MIDDLE SMOOTH, BOTTOM V. ROUGH

Age of Exposure: 3 YR Vegetation Effects: NONE



Elevation (ft) looking NW

TxDOT Rock Mass Field Description

Summary of Engineering Geologic Data

Joint Description Summary NO JOINTING

Set #	Strike	Dip	Roughness	Separation/ Filling	Persistence	Weathering	Remarks

Other Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks

Occasional Random Joints? ____________________

Bedding Description: UPPER SLOPE: 3' CAPROCK ON TOP FOLLOWED BY 13' OF SOFTER WEATHERED LS W/CALCAREOUS SILT FOLLOWED BY 2' HARD VUGGY LAYER / SOMEWHAT ... COLLAPSE FILL
MIDDLE SLOPE: HARD CRYSTALLINE BEDS, SLIGHTLY VUGGY OCC 1'-2' VOID, HIGHLY FRACTURED, BEDS 1"-3' THICK
LOWER: ALT. HARD CRYSTALLINE BEDS AND SOFT SOLUTIONED BEDS W/CLAY FILLING SOME OF THIS ROCK IS WEATHERED TO THE POINT THAT IT RAVELS LIKE SOIL WHEN HIT WITH PICK THICKNESS RANGES 6"-4' (AVG 2') MANY FRACTURES

Weathering/Erosion: SOLUTIONED BEDS WEATHERED SOMETIMES TO RESEMBLE ~~[illegible]~~ HARD SILT NONE OTHERWISE

Form of Slope Failure/Degradation: BLOCK FALL UPPER 2 SLOPES.
MINOR BLOCK FALL AND SUBSTANTIAL RAVELING OF BOTTOM

Debris: UPPER: COBBLE TO 3' BLOCKS (RANDOM) ON BENCH
MIDDLE: NUMEROUS BLOCKS 6"-7' ON BENCH
LOWER: V. LITTLE SMALL TALUS, OCC BLOCK (<1')

Maintenance Record: ____________________

Available Geotechnical Data: ____________________

TxDOT Rock Mass Field Description

Scanline Descriptions

Horizontal Scanline Number: ____ NONE
Horizontal Location (locate on sketch): ____________________
Height above base of cut (ft): ____
If w/in one layer, layer thickness: ______
Length of scanline (ft): ______
Strike of scanline (if different from face): ____________________

0+00 0+50 1+00

Scanline Sketch (include seepage locations)

Debris Description

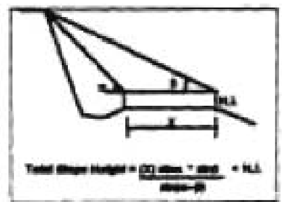
obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Condition
			+/-20	20-45	45-90	R.L.	+/-20	20-45	45-90	R.L.		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												

Set	Apparent spacing (#/scan length)	True Spacing (#/scan length)
1		
2		
3		
4		
5		

TxDOT Rock Mass Field Description

Scanline Descriptions

Vertical Scanline Number: ________
Scanline Location (show on sketch): ____________________
Height of Scanline (ft): ________
Length of Scanline(ft): ________



Scanline Sketch

EST. RQD
UPPER: 20-40
MIDDLE: 80-90
LOWER: 0-40%

Photo Listing

No.	Description
17	OVERALL FROM N.E.
18	MIDDLE SLOPE FRACTURING
19	LOWER 2 BENCHES

Samples Taken: NONE

Scanline Information:

obs #	Sta.	Set	Strike wrt to exposure				Dip wrt to exposure				Persist.	Cond'n
			+/-20	20-45	45-90	R/L	+/-20	20-45	45-90	R/L		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

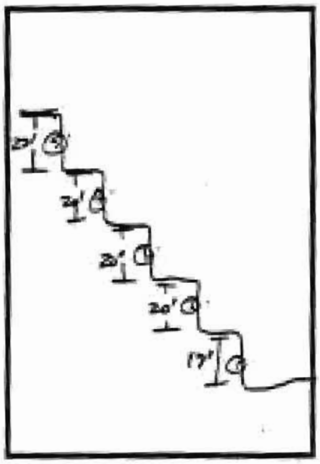
Date: 6/1/95
Page 1 of 5
Code 211-3

TxDOT Rock Mass Field Description

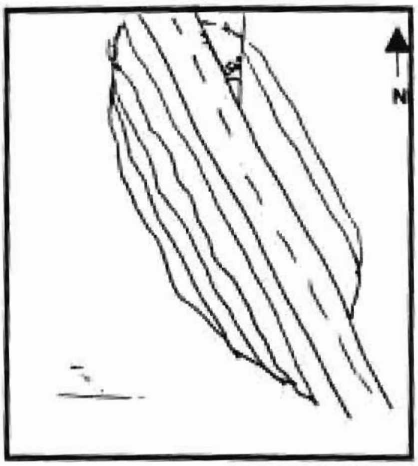
Formation: EDWARDS

Location: SH 211 ½ mi SOUTH OF SH 16

TxDOT District: SAN ANTONIO



Profile Sketch



Plan Sketch

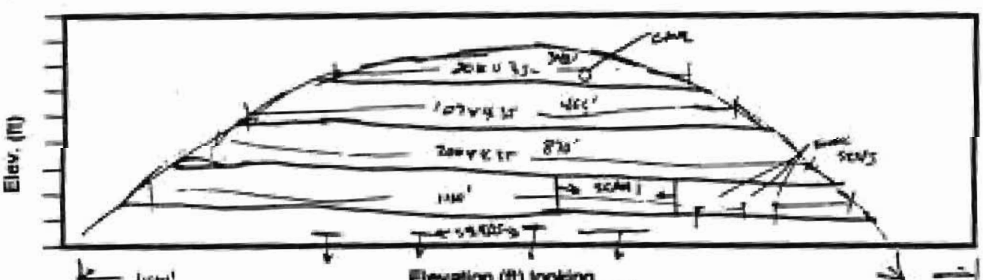
General Exposure Description

Dimensions and Orientation:

Total Height (ft): 100'
Lateral Extent (ft): 1400'
Benches: 5 Height Width SEE SKETCH NUMBERED 5→1 FROM TOP TO BOTTOM SLOPE
L1
L2
L3
Face Orientation: Strike/dip: N 50° W , AVG 80°-75° (10°-15' LAYBACK)
Catchment Description: CONC. DITCH , SET BACK
Artificial Support: NONE

Method of Excavation (incl. effects): BLAST

Age of Exposure: 3 YR Vegetation Effects:



Elevation (ft) looking

Date: 6/10/95
Page: ~~1 of 5~~ 2 of 5
Code: 211-3

SLOPE 5: 22 ft. high; 15'-17' bench
Top to Bottom: 4' hard bed, 5' hard bed, 6-1' crystalline beds, 7' hard bed. (all slightly vuggy)
Debris: None
Joints: 1 set N55E, 65SE, dip away from cut, 115' true spacing, tight/vr/u/dry/persistent.
1 set N60E, 60NW, dip into cut, 115' true spacing, same condition

SLOPE 4: 20' high, 15' bench
Top to Bottom: One massive bed alt. from crys. to vuggy to nodular
Debris: Scattered 4" - 1' blocks
Failure: minor block fall along joint/face intersection at top of slope, minor raveling
Joints: two criss-crossing sets: N45E, 60NW, 23' true spacing, vr/u/tight/dry/persis./fl
N40E, 55SE, 51' true spacing, same condition

SLOPE 3: 20' high, 15'-18' bench
Top to Bottom: One massive crystalline (porcelainic bed)
Debris: v.little
Failure: minor block at jt./face contact
Joints: two sets: N10E, 55SE, dips into cut, 40' true spacing
N70E, 65NW, dips into cut, 26' true spacing
Both sets generally tight but up to 25 mm separation along portions of some joints, very rough, stained, most extend entire height of slope 3, 50% filled with fine grained soil.

SLOPE 2: 20' high, 20'-25' wide bench
Top to Bottom: 5', 4', 4', hard crys. beds (sl. vuggy), followed by 7' of 1'-2' highly fractured hard beds
Debris: v. little. sporadic 2' block
Failure: None observed, however, loose blocks observed at top of slope (2'-5' block size).

SEE SCANLINE FOR JOINTING INFORMATION

SLOPE 1: 17' high
Top to Bottom: 7' of 1'-3' hard highly fractured beds followed by 10' of 3"-2' softer dolomitic and marly beds. Solution collapses observed in both portions of slope. Seepage along bedding planes in lower 10 of slope.
Debris: soil to 1.5' boulder at toe and in ditch.
Failure: Raveling, spalling

TxDOT Rock Mass Field Description

Summary of Engineering Geologic Data

Joint Description Summary

Set #	Strike	Dip	Roughness	Separation/ Filling	Persistence	Weathering	Remarks
		P.2					
	SEE						
		JOINTS	DO NOT	APPEAR TO	GO TO SLOPE!		

Other Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks

Occasional Random Joints? ____________________

Bedding Description: SEE P. 2

Weathering/Erosion: SEE P. 2

Form of Slope Failure/Degradation: SLOPES 5-2: MINOR BLOCK FALL 6"-3'
SLOPE 1: BLOCK FALL, RAVELLING (BOTH MINOR)

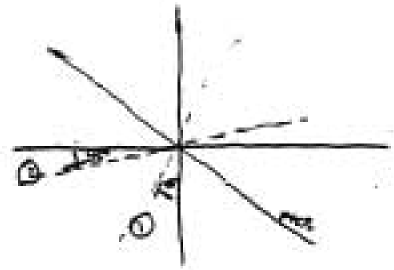
Debris: SEE PAGE 2

Maintenance Record: ____________________

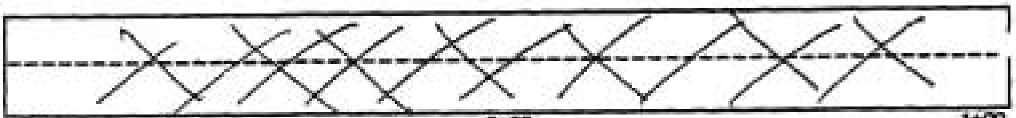
Available Geotechnical Data: ____________________

TxDOT Rock Mass Field Description

Scanline Descriptions



Horizontal Scanline Number: 1
Horizontal Location (locate on sketch): SLOPE 2 SEE SKETCH
Height above base of cut (ft): 5'
If w/in one layer, layer thickness: ______
Length of scanline (ft): 100'
Strike of scanline (if different from face): ______



0+00 0+50 1+00

Scanline Sketch (include seepage locations)

SET 1 N30°E, 45°SE (INTO)
SET 2 N70°E, 45° NW (INTO)

Debris Description

obs #	Sta.	Set	Strike w/r to exposure +/-20	20-45	45-90	R/L	Dip w/r to exposure +/-20	20-45	45-90	R/L	Persist.	Condition
1		1			X	R		X		L	P	TITE w/ VR, U/DRY/NO REL
2		2			X	L		X		R	P	" " " " "
3												
4												
5												
6												
7												
8												
9												
10												
11	–											
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												

Set	Apparent spacing (#/scan length)	True Spacing (#/scan length)	
1	8.3'	8'	~~||||~~ ~~||||~~ ||
2	17'	16'	~~||||~~ ||
3			
4			
5			

TxDOT Rock Mass Field Description

Scanline Descriptions

Vertical Scanline Number: ________
Scanline Location (show on sketch): ________
Height of Scanline (ft): ________
Length of Scanline(ft): ________

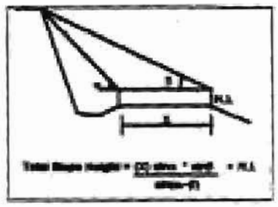


Photo Listing

No.	Description
20	PANORAMIC / EG- N...
21	SLOPE 3
1	BLOCK FALL SLOPE 2
2	
3	
4	
5	
6	COLLAPSE: SLOPE 1

Scanline Sketch

EST RQDs: 20 - 95
SLOPE 4.2 SLOPE 4.

Samples Taken: ________

Scanline Information:

obs #	Sta.	Set	Strike w/r to exposure +/-20	20-45	45-90	R/L	Dip w/r to exposure +/-20	20-45	45-90	R/L	Persist.	Cond'n
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

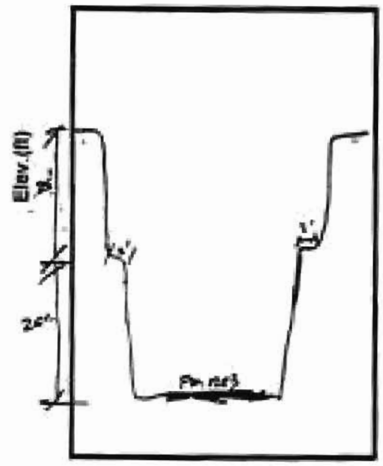
Date: 6/4/95 ✓
Page 1 of 4
Code 1283-1

TxDOT Rock Mass Field Description

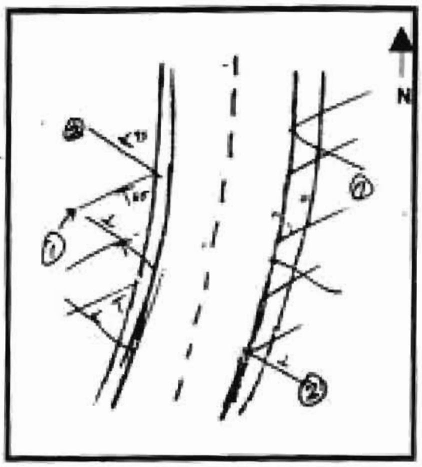
Formation: GLEN ROSE

Location: FM 1283 @ Co. RD 270 IN MEDINA COUNTY NEAR LAKE MEDINA

TxDOT District: SAN ANTONIO



Profile Sketch LKG. SO.



Plan Sketch

General Exposure Description

Dimensions and Orientation:

Total Height (ft): 50'

Lateral Extent (ft): 175 x 4.35 ≈ 750'

Benches: Height Width

L1 ______

L2 ______

L3 ______

Face Orientation: Strike/dip: N 45°E @ S. END → DUE N. @ N END / @ 78° (12° LH MKR

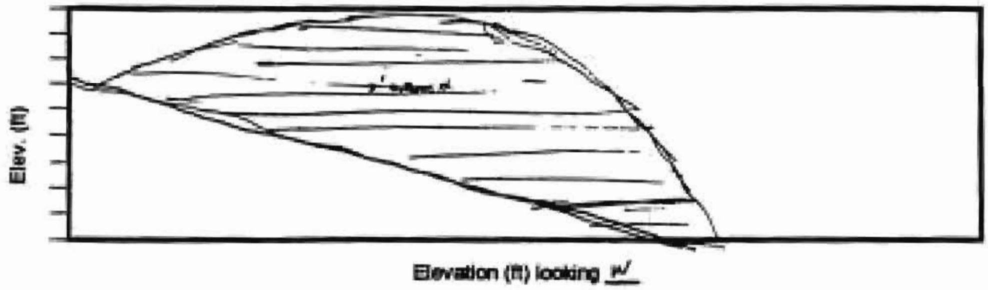
Catchment Description: NONE, SET BACK 25' FROM EOP

Artificial Support: NONE

Method of Excavation (incl. effects): BLAST, NONE

Age of Exposure: ______

Vegetation Effects: SPARSE DEPRESSION WEED, OCC GRASS



Elevation (ft) looking W

TxDOT Rock Mass Field Description

Summary of Engineering Geologic Data

Joint Description Summary

Set #	Strike	Dip	Roughness	Separation/ Filling	Persistence	Weathering	Remarks
1	N 50°E	65° SE	VR. PLANAR	TITE → 1/8"	GENERALLY	II	NO FILLING
2	N 60°W	75° NE	R/UND	TITE	THROUGH		
					GOING	II	
					CONTINUES TO		
					LOWER 20' of		
					SLOPE		

Other Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks

Occasional Random Joints? YES BED CONFINED

Bedding Description: RANGE FROM 2' 7. MASSIVE w/ AVE 6'
NO MARLY BEDS OBSERVED

Weathering/Erosion: DISCOLORATION OF FACE, NONE OTHERWISE

Form of Slope Failure/Degradation: OCC SMALL BLOCK (1'±) FROM LOWER BED @ TOE OF LOWER SLOPE AND @ JT INTERSECTION W/FACE

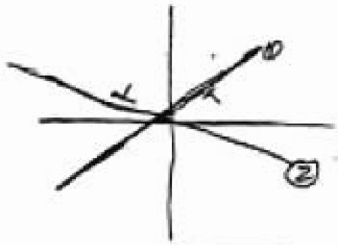
Debris: OCC COBBLE SIZE FRAGS.

Maintenance Record:

Available Geotechnical Data:

TxDOT Rock Mass Field Description

Scanline Descriptions



Horizontal Scanline Number: 1
Horizontal Location (locate on sketch): ENTIRE CUT
Height above base of cut (ft): 20'
If w/in one layer, layer thickness: [illegible]
Length of scanline (ft): ENTIRE CUT
Strike of scanline (if different from face):

0+00 0+50 1+00

Scanline Sketch (include seepage locations)

Debris Description

WEST FACE

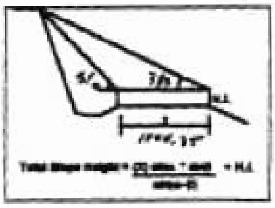
obs #	Sta.	Set	Strike w/r to exposure +/-20	20-45	45-90	R/L	Dip w/r to exposure +/-20	20-45	45-90	R/L	Persist.	Condition
1		1			X	L		X		R	P	VR/P-U/DRY/II/TITS 70%" NO FILL
2		2			X	R	X			R	[illegible]	VR/U/DRY/II/TIT2/NO FILL
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												

Set	Apparent spacing (#/scan length)	True Spacing (#/scan length)
1	36'	38'
2	54'	47'
3		
4		
5		

TxDOT Rock Mass Field Description

Scanline Descriptions

Vertical Scanline Number: ________
Scanline Location (show on sketch): ________
Height of Scanline (ft): ________
Length of Scanline(ft): ________



Scanline Sketch

Est RQD
60 - 70

Photo Listing

No.	Description
2	PANORAMIC LKG NW
3	JOINTS

Samples Taken: NONE

Scanline Information:

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Cond'n
			+/-20	20-45	45-90	R/L	+/-20	20-45	45-90	R/L		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

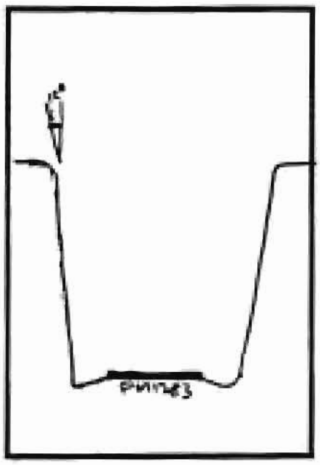
Date: 6/10/95 ✓
Page 1 of 4
Code 1283-2

TxDOT Rock Mass Field Description

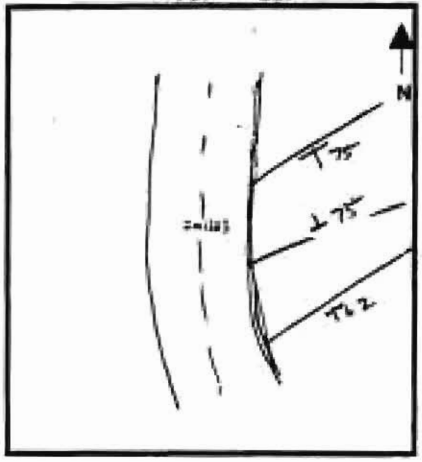
Formation: EDWARDS

Location: FM 1283 ~~[illegible]~~ 4.5 MI S. OF R.R. 37 IN MEDINA CO.

TxDOT District: SAN ANTONIO



Profile Sketch



Plan Sketch

General Exposure Description

Dimensions and Orientation:

Total Height (ft): 30'-35'

Lateral Extent (ft): 130 x 4.35 = 565'

Benches: Height Width

L1 ____

L2 ____

L3 ____

Face Orientation: Strike/dip: DUE N. @ N. END TO N 15°W @ SOUTH END, 78°-80°

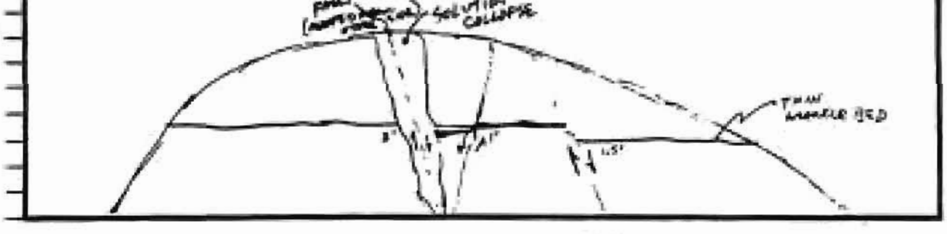
Catchment Description: SHALLOW DITCH, SET BACK 20' FROM EOP

Artificial Support: NONE

Method of Excavation (incl. effects): BLAST - SMOOTH WALL

Age of Exposure: ____

Vegetation Effects: SPARSE GRASS CLUMPS IN SOIL FILLED POCKETS



Elevation (ft) looking EAST

TxDOT Rock Mass Field Description

Summary of Engineering Geologic Data

Joint Description Summary

Set #	Strike	Dip	Roughness	Separation/ Filling	Persistence	Weathering	Remarks
1	N15°E	90°	VR/U	T/TS	[illegible]	STAINING	
2	N[illegible]	90	VR/U	T-[illegible]	[illegible]	ST	
3	N 60 E	65SE	VR/U	T-TS	[illegible]	ST	

Other Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks
FAULT	N 60 E	32°SE	VR/U/DRY/½"	[illegible]	½" APERTURE W/ SILT, CLAY, GRAVEL FILLING 1.5 DISP.
"	N 65 E	75° NW	VR/U/DRY/½"	" "	[illegible] ½" AP. W/ [illegible], ±1' DISPLACEMENT
"	N 60 E	75°SE	VR/U/DRY/½"-1"	" "	½"-1" AP. [illegible], [illegible] SECTION CUT, 2' DISP

Occasional Random Joints? YES BED CONFINED, NEAR VERTICAL FRACTURES

Bedding Description: HARD CRYSTALLINE. <1' TO 8' W/ AVG 5'-6' THICK SOLUTION COLLAPSE ZONE AS SHOWN ON SKETCH, OCC THIN BEDS (3"-6") SEPARATING THICKER BEDS.

Weathering/Erosion: NONE EXCEPT ~~[illegible]~~ WASHOUT OF SOLUTION COLLAPSE. FEATURE IS [illegible] WIDE, EXTENDS ENTIRE HEIGHT OF SLOPE AND IS ERODED BACK 6'-10' FROM FACE (SEE PHOTOS)

Form of Slope Failure/Degradation: VERY VERY MINOR SPALLING OCC. SMALL BLOCK.

Debris: SPARSE 4" - 1' LS FRAGMENTS, TALUS PILE AT BASE OF SOLUTION COLLAPSE

Maintenance Record:

Available Geotechnical Data:

TxDOT Rock Mass Field Description

Scanline Descriptions

Horizontal Scanline Number: 1
Horizontal Location (locate on sketch): BATTIER CUT (EAST FACE)
Height above base of cut (ft): 6'-8'
If w/in one layer, layer thickness: ______
Length of scanline (ft): BATTIER CUT
Strike of scanline (if different from face): ______

0+00 0+50 1+00

Scanline Sketch (include seepage locations)

Debris Description

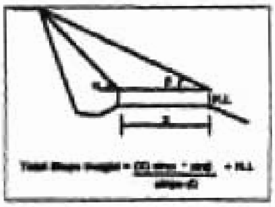
obs #	Sta.	Set	Strike w/r to exposure +/-20	Strike w/r to exposure 20-45	Strike w/r to exposure 45-90	Strike w/r to exposure R/L	Dip w/r to exposure +/-20	Dip w/r to exposure 20-45	Dip w/r to exposure 45-90	Dip w/r to exposure R/L	Persist.	Condition
1		1	X			R	X			H/H	PERS.	VR/U/DRY/TITE/II
2		2		X		R	X			H/H	PERS.	" " " "
3		3			X	R		X		R	LOWER H/H	VR/U/DRY/OPEN 1/4"/II/ NO FILL
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												

Set	Apparent spacing (ft/scan length)	True Spacing (ft/scan length)
1	113'	29'
2	106'	44'
3	81'	30'
4		
5		

TxDOT Rock Mass Field Description

Scanline Descriptions

Vertical Scanline Number: ________
Scanline Location (show on sketch): ________
Height of Scanline (ft): ________
Length of Scanline(ft): ________



Scanline Sketch

Photo Listing

No.	Description
8	FAULT
9	FAULT
10	PANORAMIC LKG NE

Samples Taken: NONE

EST. RQD
70 – 80
IN INTACT PORTIONS OF
WT (I.E. NOT AT FAULT ZONES)

Scanline Information:

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Cond'n
			+/-20	20-45	45-90	R/L	+/-20	20-45	45-90	R/L		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

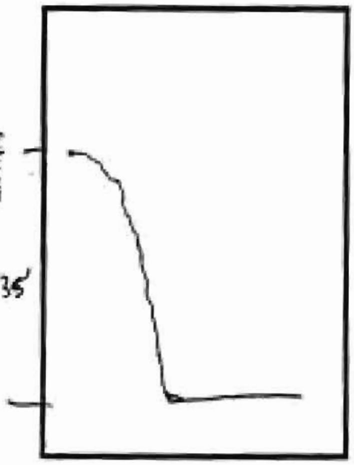
Date: 6/3/95
Page 1 of 4
Code 173-1

TxDOT Rock Mass Field Description

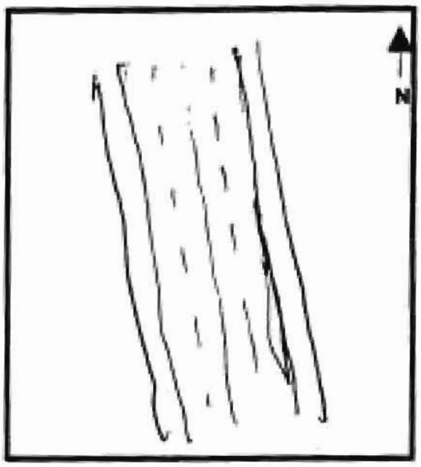
Formation: EDWARDS

Location: S.H. 173 N. OF HONDO (MEDINA CO. IN ED. AQUIFER RECHARGE ZONE

TxDOT District: SAN ANTONIO



Profile Sketch



Plan Sketch

General Exposure Description

Dimensions and Orientation:

Total Height (ft): 50'

Lateral Extent (ft): [illegible] ± 35 + 250' ≈ 1100'

[illegible]: Height Width

L1 ______

L2 ______

L3 ______

SLOPE APPEARS VERY BLOCKY ON THE FACE BUT NO SIGNIFICANT BLOCK FALL (IF ROCK BLOCKS ARE [illegible] FRACTURED LIKE FACE, [illegible] WOULD BE LOW (SOUND)

Face Orientation: Strike/dip: N 10° W, 80°-70° (VARIES

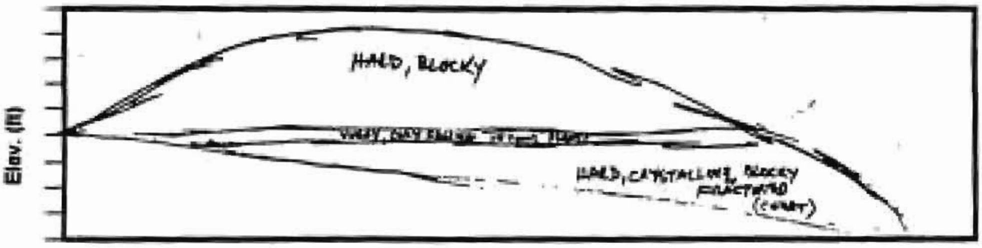
Catchment Description: ~~[illegible]~~ PAVED SHALLOW DITCH TO TOE

Artificial Support: NONE

Method of Excavation (incl. effects): ASSUME BLAST BUT SURFACE IS ROUGH, UNDULATING AND NO SHOT HOLES OBSERVED. NOT SMOOTH WALL BLAST

Age of Exposure: ______

Vegetation Effects: SOME CACTUS, YUCCA, SHRUBS GROWING FROM SOIL FILLED VOIDS



Elevation (ft) looking EAST

TxDOT Rock Mass Field Description

Summary of Engineering Geologic Data

Joint Description Summary

Set #	Strike	Dip	Roughness	Separation/ Filling	Persistence	Weathering	Remarks

Other Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks

Occasional Random Joints? YES, BUT BED CONFINED.

Bedding Description: 3' TO MASSIVE. HARD BEDS (ALL BUT VUGGY LAYER) ARE HIGHLY FRACTURED RESULTING BLOCKY APPEARANCE ON FACE BUT FRACTURES ARE VERY TIGHT IN GENERAL (OPEN WHERE SM. BLOCKS ARE LOOSE)
GENTLE FOLDING

Weathering/Erosion: VUGGY SOLUTIONED LAYER HAS ERODED BACK SLIGHTLY CREATING 1-2' LOCALIZED CANTILEVERS. NO SEEPAGE

Form of Slope Failure/Degradation: LOCALIZED SM. BLOCKS, RAVELLING (V. MINOR)
BLOCK SIZE SEEMS TO VARY FROM SEVERAL INCHES TO 3'.

Debris: V. LITTLE GRAVEL TO COBBLE SIZE

Maintenance Record:

Available Geotechnical Data:

TxDOT Rock Mass Field Description

Scanline Descriptions

NONE CONDUCTED. DISC'S TIGHT, FREQUENT BUT BED CONFINED. MOST NEARLY VERTICAL.

Horizontal Scanline Number: ____
Horizontal Location (locate on sketch): ____________________
Height above base of cut (ft): _____
If w/in one layer, layer thickness: ________
Length of scanline (ft): __________
Strike of scanline (if different from face): ____________________

0+00 0+50 1+00

Scanline Sketch (include seepage locations)

Debris Description

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Condition
			+/-20	20-45	45-60	R/L	+/-20	20-45	45-60	R/L		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												

Set	Apparent spacing (#/scan length)	True Spacing (#/scan length)
1		
2		
3		
4		
5		

TxDOT Rock Mass Field Description

Scanline Descriptions

Vertical Scanline Number: ________
Scanline Location (show on sketch): ________
Height of Scanline (ft): ________
Length of Scanline(ft): ________

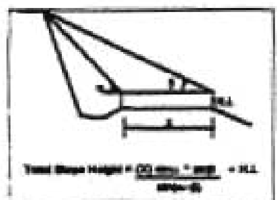


Photo Listing

No.	Description
4-4	

Scanline Sketch

EST RQD:
60-90

Samples Taken: NONE

Scanline Information:

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Cond'n
			+/-20	20-45	45-90	R/L	+/-20	20-45	45-90	R/L		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

Date: 5/18/05
Page 1 of 4
Code I-10-2

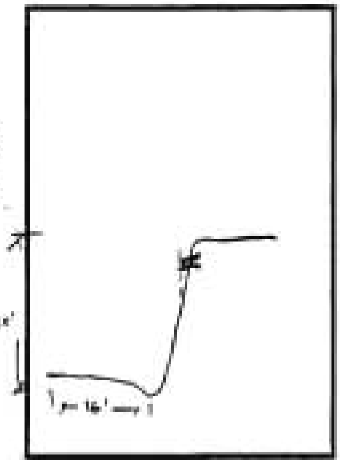
TxDOT Rock Mass Field Description

~~Glen Rose Formation~~ FORT TERRET

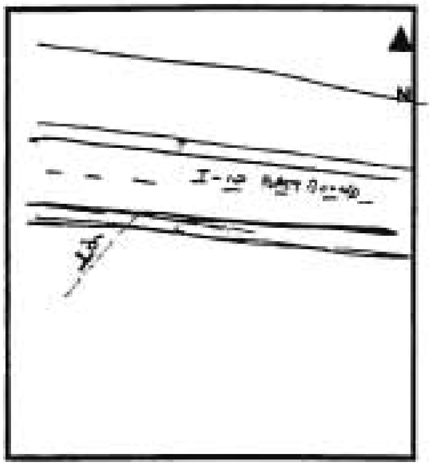
Location: I-10 EA BOUND, 1.5 mi east of Hwy 16 (KERRVILLE)

TxDOT District: San Antonio

Elev. (ft)



Profile Sketch



Plan Sketch

General Exposure Description

Dimensions and Orientation:

Total Height (ft): 25'

Lateral Extent (ft): 165 x 4.35 = 720'

~~Benches~~: Height Width

L1

L2

L3

Face Orientation: Strike/dip: N80W, 78° N

Catchment Description: 16' from road, 2' ditch at toe

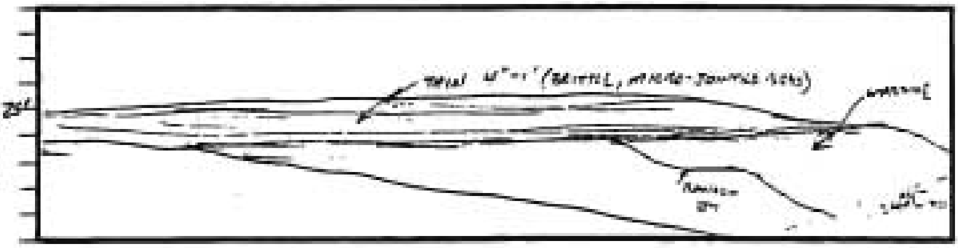
Artificial Support: None

Method of Excavation (incl. effects): BLAST

Age of Exposure:

Vegetation Effects: GRASS, BRUSH, CEDARS GROWING OUT OF FACE

Elev. (ft)



Elevation (ft) looking SOUTH

TxDOT Rock Mass Field Description
Glen Rose Formation

Summary of Engineering Geologic Data

Joint Description Summary

Set #	Strike	Dip	Roughness	Separation/ Filling	Persistence	Weathering	Remarks
1 JOINT	N 20 E	75°	V ROUGH	TIGHT → 1"	BC	II	

Other Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks

Occasional Random Joints? ONLY 2 JOINTS IN ENTIRE CUT OBSERVED (ONE NOTED ABOVE, OTHER ON SKETCH)

Bedding Description: AT MAX HEIGHT: UPPER 10' IS 4"-1" BEDS, BRITTLE/BLOCKY(CURVED) LOWER 15' IS ONE MASSIVE BED (BURROWED)

Weathering/Erosion: NONE TO SPEAK OF

Form of Slope Failure/Degradation: VERY MINOR RAVELLING · EVIDENCE OF 2 LOCATIONS OF BLOCK FALL NEAR W. END (SEE P-19) WEST END IS HIGHLY FRACTURED W/ BLOCK SIZES MAYBE 1' – 3' (P-19), SOME LOOSE, BROKEN BLOCKS

Debris: VERY LITTLE (COBBLE SIZE)

Maintenance Record:

Available Geotechnical Data:

TxDOT Rock Mass Field Description
Glen Rose Formation

Scanline Descriptions

Horizontal Scanline Number: ____
Horizontal Location (locate on sketch): ____________________
Height above base of cut (ft): _____
If w/in one layer, layer thickness: ________
Length of scanline (ft): ________
Strike of scanline (if different from face): ____________________

0+00 0+50 1+00

Scanline Sketch (include seepage locations)

Debris Description

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Condition
			+/-20	20-45	45-90	R/L	+/-20	20-45	45-90	R/L		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												

Set	Apparent spacing (#/scan length)	True Spacing (#/scan length)
1		
2		
3		
4		
5		

TxDOT Rock Mass Field Description
Glen Rose Formation

Code I 10 [illegible]

Scanline Descriptions

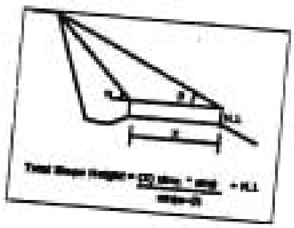
Vertical Scanline Number: ______
Scanline Location (show on sketch): ______
Height of Scanline (ft): ______
Length of Scanline(ft): ______

Scanline Sketch

P-19 – FRACTURED ZONE, JT ~~[illegible]~~ in RND. LKG SW

P-20 STRIPPED JT LKG SW

P-21 OBLIQUE LKG SW



Fracture frequency: ______
Est. RQD: 50-60 WEST END
70-80-90 IN REMAINDER

Scanline Information:

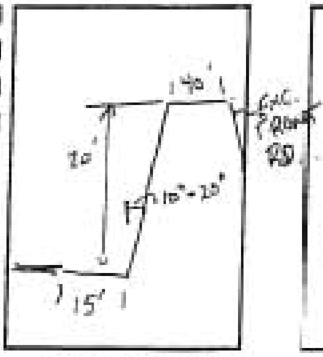
obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Cond'n
			+/-20	20-45	45-90	Rd.	+/-20	20-45	45-60	Rd.		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												

TxDOT Rock Mass Field Description

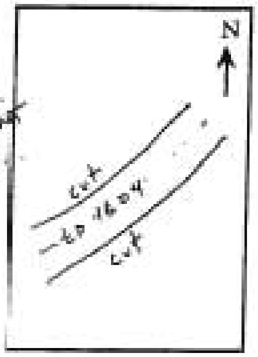
Code S-1

Page 1 of 4

Elevation (ft) (add scale)



Profile Sketch



Plan/Map Sketch

Field Crew: MJG, BEM RJW

Date: 7/13/94

Location: Bitters Road @ Loop 1604

TxDOT District: San Antonio

Geologic Formation: Edwards Limestone

General Exposure Description

Dimensions and Orientation

Total height (ft) 20

Lateral Extent (ft): ≅1200'

Benches: number of levels: Ø height (ft): ______ width (ft) ______

Face orientation: strike/dip N 42° E

Catchment Description: Ditch (grassy) ≅15' wide

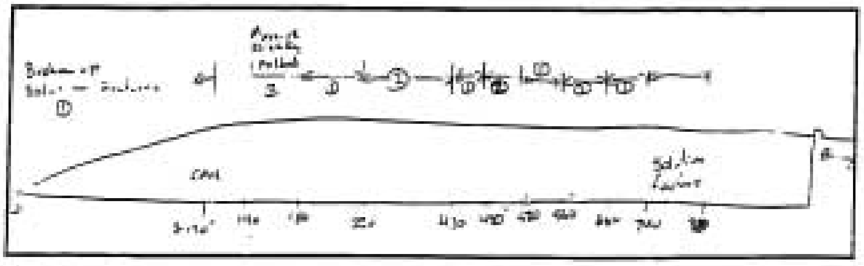
Support Installed: Anchored – cast-in-place wall at bridge abutment

Method of Excavation (if blasted, describe blast effects) Blasted 3' O.C. Some fracturing at ½-casts accompanied by sub-parallel jointing – 20° into slope

Age of Exposure 4 Years

Vegetation Effects None

Elevation (ft) (add scale)



Elevation Sketch of Exposure (ft) (add scale)
(looking east)

TxDOT Rock Mass Field Description

Code S-1
Page 2 of 4

Summary Geologic Description

Bedding Description: Strike/dip: ________

	Layer	Thickness	Geologic Formation	Physical Properties	Remarks	Samples Taken
TOP	5	1'	EDWARDS	MASSIVE	CAPROCK	NO
	4	1/2'		DARK CLAY/KARST FOR SOLUTION DEPOSITS		
	3	10'		MASSIVE		
	2	1/2'				
BOTTOM	1	8'		MASSIVE		

Joint Description Summary

Joint Set	Strike	Dip	Condition	Persistence

Major Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks

Differential Weathering: Collapse/Sinkhole Areas Show Accelerated Erosion Otherwise Little Weathering is Evident (confined to thin beds)

Active Erosion: Mostly Confined To Areas of Solution Collapse/Sinkhole

Geotechnical Data (core available, site investigation report?): ________

Form of Slope Degradation: ________

TxDOT Contact: Gilbert Garza

TxDOT Record of Maintenance: None

TxDOT Rock Mass Field Description

Code 5-1

Scanline Descriptions

Horizontal Scanline Number: ___

Horizontal Location (key into profile sketch and elevation sketch): ______

Height above base of cut (ft): ______

If within one layer, layer thickness (ft): ____

Length of scanline (ft): _____

Strike of scanline: ________

No Jointing Noted

0+00 0+50 1+00

Scanline Sketch (stationing in ft, include seepage locations)

Small blocks in ditch

Debris Description

Scanline Information:

Obsⁿ	Station	Set	Strike (w/r to exposure)				Dip (w/r to exposure)				Persist	Cond'n	Remarks
			±20°	20-45°	45-90°	R/L	±20°	20-45°	45-90°	R/L			
1													
2													
3													
4													
5													
6													

Description Keys:

Strike or Dip: R = into slope to the right
L = into the slope to the left

Condition: Closed: rough, undulating, planar, slickensided
Filled: sandy, clayey, gouge, filling thickness

Persistence: exposed length (ft)
continuous through outcrop
bed-confined
termination index:
T
S
R

Debris: Estimated block size (ft)
Joint or blast formation
Differential Weathering

TxDOT Rock Mass Field Description

Code 5 -1

Scanline Descriptions

Vertical Scanline Number: 1

Scanline Location (key into profile sketch and elevation sketch): ________

Height of scanline (ft): C

Length of scanline: [illegible]

Elevation (ft) (add scale)

[illegible]
[illegible]

Scanline Sketch

Scanline Information:

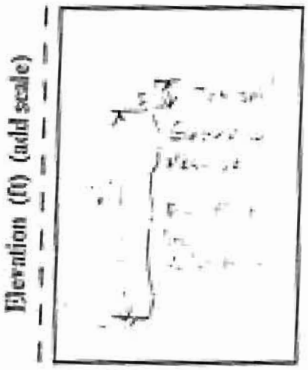
Obsn	Station	Set	Strike (w/r to exposure)				Dip (w/r to exposure)				Persist	Cond'n	Remarks
			±20°	20-45°	45-90°	R/L	±20°	20-45°	45-90°	R/L			
1													
2													
3													
4													
5													
6													

Fracture Frequency (disc/ft): ______

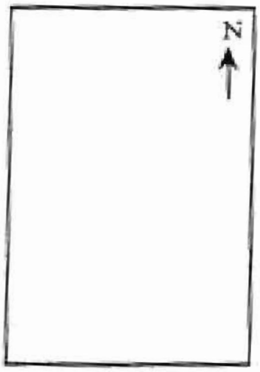
Estimated RQD: 75-90 Non
40-65 Solutioned

TxDOT Rock Mass Field Description

Code 5-2



Profile Sketch



Plan/Map Sketch

Field Crew: TMTG RJW, BFM

Date:

Location: Loop 1604 @ Gold Canyon Road

TxDOT District: San Antonio

Geologic Formation: EDWARDS

General Exposure Description

Dimensions and Orientation

Total height (ft) 18'

Lateral Extent (ft):

Benches: number of levels: 0 height (ft): ______ width (ft) ______

Face orientation: strike/dip

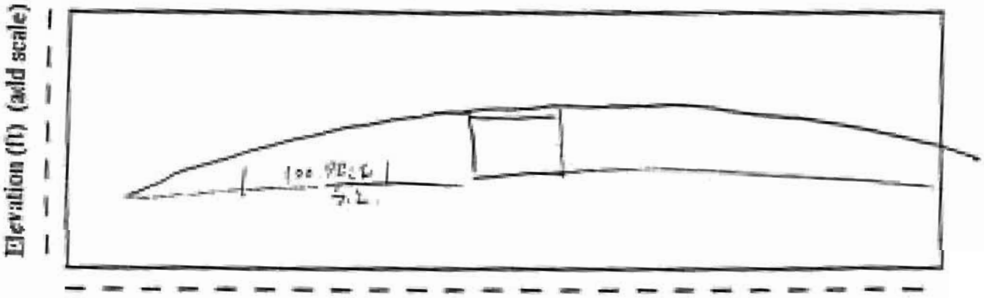
Catchment Description: NONE CONSTRUCTED

Support Installed:

Method of Excavation (if blasted, describe blast effects) BLASTED

Age of Exposure Fresh

Vegetation Effects None



Elevation Sketch of Exposure (ft) (add scale)

TxDOT Rock Mass Field Description

Code S-2

Summary Geologic Description

Bedding Description: Strike/dip: ________

Layer	Thickness	Geologic Formation	Physical Properties	Remarks	Samples Taken
2	5'			WEATHERED	
1	13'			VUGGY	

Joint Description Summary

Joint Set	Strike	Dip	Condition	Persistence
A				
B				

Major Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks

Differential Weathering: WEATHERED

Active Erosion: NONE YET

Geotechnical Data (core available, site investigation report?): ________

Form of Slope Degradation: ________

TxDOT Contact: Elbert Gaxiola

TxDOT Record of Maintenance: NONE

TxDOT Rock Mass Field Description

Code S-2
Page 3 of 4

Scanline Descriptions

Horizontal Scanline Number: 1

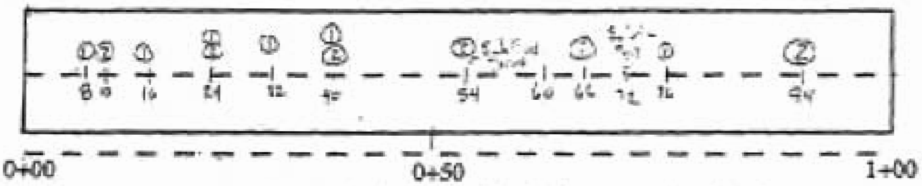
Horizontal Location (key into profile sketch and elevation sketch): ______

Height above base of cut (ft): 4

If within one layer, layer thickness (ft): 6'

Length of scanline (ft): 140'

Strike of scanline: ______



Scanline Sketch (stationing in ft, include seepage locations)

Debris Description

Scanline Information:

Obs #	Station	Set	Strike (w/r to exposure)				Dip (w/r to exposure)				Persist	Cond'n	Remarks
			±20°	20-45°	45-90°	R/L	±20°	20-45°	45-90°	R/L			
1		1		✓		L			✓	L		Rough	closed
2		2			✓	R			✓	R		"	"
3													
4													
5													
6													

Description Keys:

Strike or Dip: R = into slope to the right
L = into the slope to the left

Condition: Closed: rough, undulating, planar, slickensided
Filled: sandy, clayey, gouge, filling thickness

Persistence: exposed length (ft), continuous through outcrop, bed-confined, termination index: T, S, R

Debris: Estimated block size (ft), Joint or blast formation, Differential Weathering

TxDOT Rock Mass Field Description

Code S-2

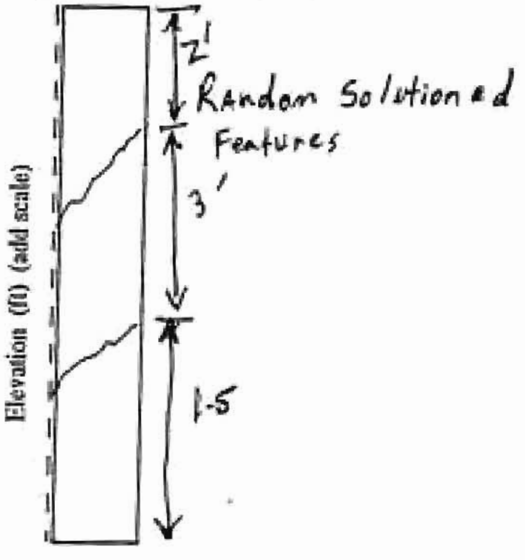
Scanline Descriptions

Vertical Scanline Number: ____

Scanline Location (key into profile sketch and elevation sketch): ________

Height of scanline (ft): ____

Length of scanline: 6.5'



Scanline Sketch

Scanline Information:

Obs'n	Station	Set	Strike (w/r to exposure)				Dip (w/r to exposure)				Persist	Cond'n	Remarks
			±20°	20-45°	45-90°	R/L	±20°	20-45°	45-90°	R/L			
1													
2													
3													
4													
5													
6													

Fracture Frequency (disc/ft): ______

Solutioned
Estimated RQD: 45-60
Non Solutioned 60-75

APPENDIX B

Maintenance Data

Table B.1. Maintenance Information for Austin District Sites.

Site Code	Geologic Formation	Type of Failure	Age of Cut (years)	Maintenance requirements and type and size of debris	Does debris reach road? (Y/N, Freq.)	Additional comments	MR[1]
360-1	Kgr	R,W,DE	10	**Clean cobble to 1m size rocks, from ditch 1-2x/yr	Y, "occasionally"	Failure after rain	2
360-2	Ked, Kwa, Kgr	R	18,7	**Before benching in 1988, cleaned debris (cobble to 1.2m) from road and ditch 5-10x/yr. After benching, clean ditch only 2 to 3x/yr.	Y (before 1988), 5-6x/yr	Benching resulted in 50% reduction in maintenance effort in the entire Travis South maintenance section. Failures occur after rain. Most degradation is due to ravelling of Walnut Formation which is only exposed in the upper bench.	0-1
360-3	Kgr	R	18	None	N		3
620-1	Kgr	R, possible DE	<1	N/A	N/A		–
620-2	Kgr	R	7	**None	N		3
2244-1	Kgr	R	7	Clear 0.3-0.6m rock from ditch, 1x every 2-3yr	N	Failure after rain.	3
2244-2	Kgr	R,DE	7	Clear 0.3-0.6m rock from ditch, 1x every 2-3yr	N	Failure after heavy rain.	3
SWP-1	Kgr	R,DE	8	None	N	Failure after rain, constant seepage onto road.	3
SRR-1	Kgr	R,DE	6-7	0.45-0.6m rocks cleared from road every 2-3 months	Y, 4-6x/yr	Failure after rain, constant seepage	0
Au-1	Kgr	R,DE	20-25	Clean debris up to 2.5m size from road and ditch, 4-5x/yr	Y	Slope was scaled 3 to 4 years ago. Failures occur after heavy rain.	0
Au-2	Kgr	R,DE	5-6	No maintenance, cut is in drainage channel	N/A	Would require maintenance if located along roadway.	0-1
Au-3	Ked	R	22	No information	N		N/A
Au-4	Ked	R,DE	40-45	Occasional small rocks (< 0.5m) cleaned from paved ditch every 2-3 yr.	N	Has performed better over time	3

Notes: ** performance affected by benching
[1]MR = Maintenance Rating (Table 5.5)

Table B.2. Maintenance Information for Dallas and Ft. Worth District Sites.

Site Code	Geologic Formation	Type of Failure	Age of Cut (years)	Maintenance requirements and type and size of debris	Does debris reach road? (Y/N, Freq.)	MR[1]
D-1	Austin Chalk, Eagle Ford Shale	R,DE	15	Prior to 1986 cleared rock and soil debris from road 2x/yr. Guard rail installed in 1986. Rail removed, rock debris cleared, and rail reinstalled in 1995.	Y (prior to installation of guard rail). 2x/yr	2
D-2	Austin Chalk	R	35	No reported maintenance prior to installation of rock-nailed wall under bridge abutment	N	3
D-3	Austin Chalk Eagle Ford Shale	C,R,DE	35	Sloughed material from Eagle Ford pushed back and re-seeded 2x/yr during rainy season	N	2
D-4	Austin Chalk	R	1	No information	No information	–
D-5	Austin Chalk	R,DE	15	No Maintenance	N	3
FW-1	Comanche Peak	B,R	17	Cobble to 1m size debris cleared from ditch 1-2x/yr.	N	2
FW-2	Winchell/Wolf Mt.		18, 1	Prior to 1994 cleared up to 0.6m debris from road 2-3x/mo. One 6x6m block on road. Re-excavated in 1994	Y, prior to re-excavation 2-3x/mo.	0

Notes: [1]MR = Maintenance Rating (Table 5.5)

Table B.3. Maintenance Information for San Antonio District Sites.

Site Code	Geologic Formation	Type of Failure	Age (yrs)	Maintenance requirements and type and size of debris	Does debris reach road? (Y/N, Freq.)	Additional comments	MR[1]
281-1	Kgr	R,DE	32	Clear cobble to small boulder size debris 2x/yr	N	Dependent on rainfall	2
281-2	Kgr	R,W	32	Clear 1m to cobble size debris 1x every 5 yr.	N		3
281-3	Kgr	R,DE	32	Clear soil to 0.9m debris from ditch 3-4x/yr. One 1.2x2.5m block.	N	Most problematic slope in Boerne maintenance section. Rainfall dependent	0-1
281-4	Kgr	P,R	32	Clear cobble to 0.9m size debris 2-3x/yr.	N		1
281-5	Kgr	P,R	32	Clear cobble to 0.6m size debris 2-3x/yr.	N		1
1376-1	Kgr	R	40	Clear 0.3-0.6m debris from road 3-4x/yr.	Y, 3-4x/yr		0-1
1376-2	Kgr	R,T	40	Clear soil to 0.6m debris from road 5-6x/yr. In last 25 yrs, a 1.8x3.6m block has fallen onto roadway.	Y, 5-6x/yr	Rainfall dependent	0
I-10-5	Kgr	R,DE	25	Occasional 0.9m rock cleared from easement for mower access, 1x/2-3yr	N	Rainfall dependent	3
2722-1	Kgr	R	25,15	**0.9 to 1.2m blocks cleared from road (1-2x/yr) prior to benching 15 years ago. No maintenance after bench was constructed.	Y, prior to benching		2
2673-1	Kgr	R,DE	25	0.3-0.9m rocks cleared from ditch and road 1x/yr.	Y, 1x/yr.	Failures occur after hard rain	2
3159-1	Ked	R	15-20	Occasional 0.3-0.9m rock cleared for mower access.	N		2-3
I-10-1	Ked/Kgr	R, DE(Kgr)	25	Clear small rocks from easement 1x/yr for mower access. One 3x3.6m rock on shoulder after rain.	Y, one time after rain		2
I-10-2	Ked	R	25	Clear small rocks from easement 1x/yr for mower access	N		2
I-10-3	Ked/Kgr	R, (C,DE-Kgr)	25	**No maintenance	N	Debris is contained on benches	3
I-10-4	Ked/Kgr	R	25	Clear occasional small rock from easement 1x/yr for mower access	N		2
I-10-6	Ked	R	25	Clear occasional small rock from ditch 1x/yr for mower access	N		2
I-10-7	Ked	none	25	Very little maintenance	N		3

Table B.3. (con'd) Maintenance Information for San Antonio District Sites.

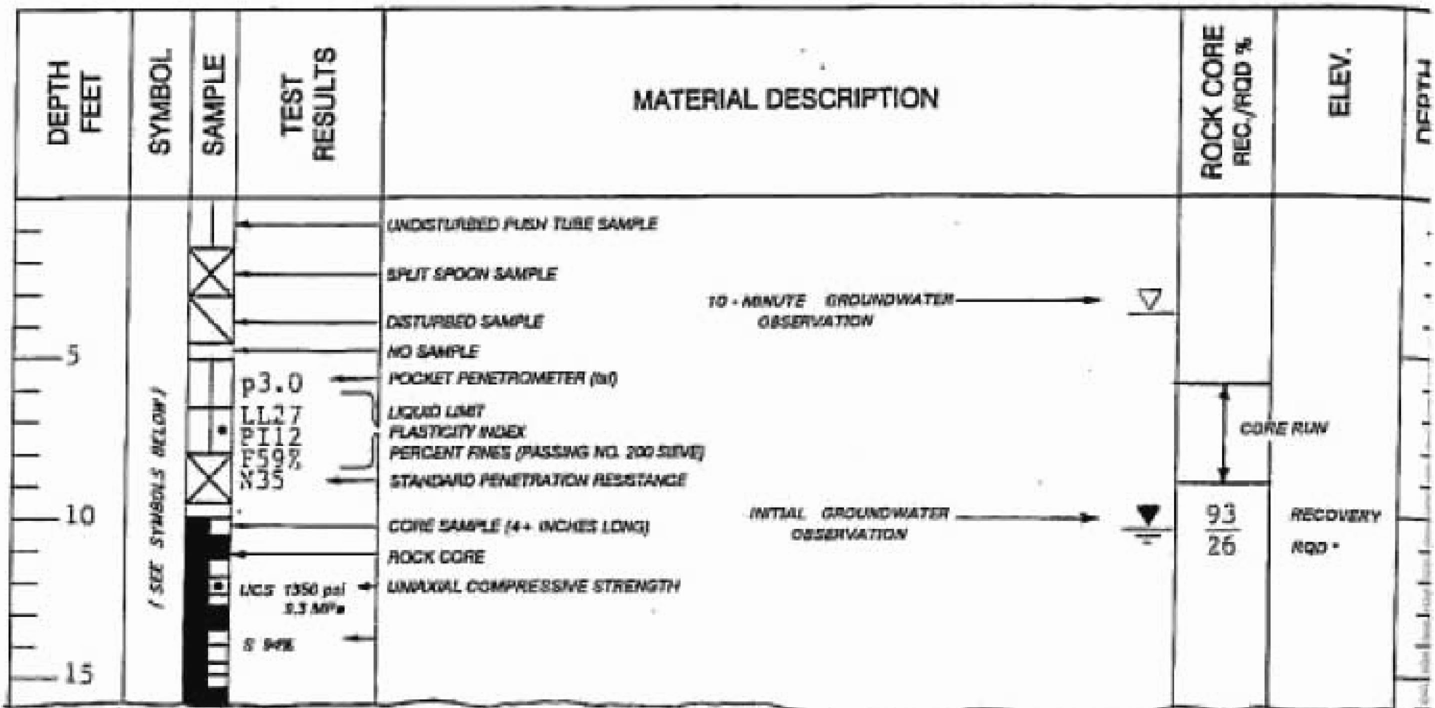
Site Code	Geologic Formation	Type of Failure	Age (yrs)	Maintenance requirements and type and size of debris	Does debris reach road? (Y/N, Freq.)	Additional comments	MR[1]
I-10-9	Ked	R	25	No maintenance	N		3
41-1	Ked	R	25-30	Clear 0.3-0.5m debris from easement 1x/yr for mower access	N		2
187-1	Ked	R	30+	Clear soil to 0.3m debris 1x/3yr	Y, 1x/3yr	Rainfall dependent	3
337-1	Ked/Kgr	R, T(Ked) DE(Kgr)	20	Clear <0.3m size debris 4-5x/yr. Scale blasting done in 1987 to remove large blocks in Ked.	Y, 4-5x/yr	Rainfall dependent, performed better over time	0
337-2	Ked	R	20	Clear up to 0.6m size debris 2-3x/yr.	Y, one time	Rainfall dependent	1
470-1	Ked/Kgr	R,DE(Kgr)	30+	Prior to installation of chain link fence, cleared soil to 1.2m debris from road 1x/yr. After fence, clear behind fence 1x/3yr.	Y, 1x/yr prior to fence	Rainfall dependent	2
211-1	Ked	R	3	**Cleared 0.3-0.9 m rocks from ditch one time.	N		3
211-2	Ked	R	3	**Cleared small number of 0.6-0.9m rocks from bench one time	N		3
211-3	Ked	R	3	**Cleared large amount of small (<0.3m) debris 2x/3yr.	N		2
1283-1	Kgr	R	18-20	Very little maintenance, small debris pushed back into ditch 1x/3yr	N		3
1283-2	Ked	R	18-20	Silt to cobble size debris from fault collapse zone cleared 1x/1.5yr	N	Fault collapse zone is source of ravelling debris, rainfall dependent	2
173-1	Ked	R	30+	No maintenance	N		3
S-1	Ked	R	5-10	Clear occasional small rock (<0.3m) from easement for mower access, 1x/yr	N		2
S-2	Ked	R	1	No maintenance	N		3

Notes: ** performance and maintenance affected by benching
[1]MR = Maintenance Rating (Table 5.5)

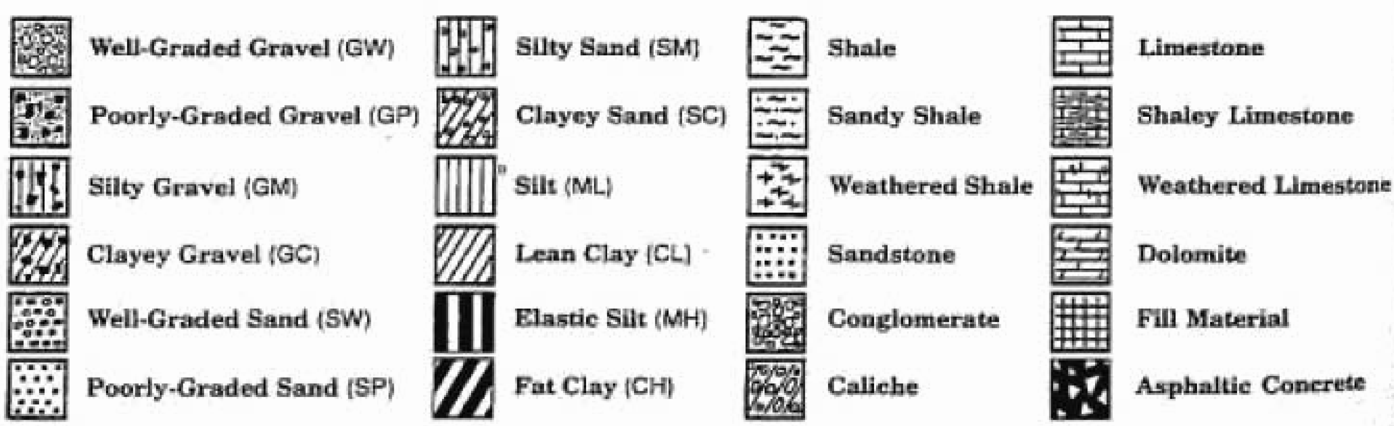
APPENDIX C

Boring Logs

EXPLANATION OF D TERMS USED ON LOGS OF BORINGS



TYPICAL SOIL AND ROCK SYMBOLS



DEGREE OF WEATHERING

Unweathered .. Rock in its natural state without visible sign of decomposition or discoloration

Slightly Weathered .... Slight discoloration without visible sign of decomposition

Weathered .... Complete discoloration with zones of slightly decomposed rock

Severely Weathered .... Complete discoloration and decomposition, approaching soil texture and appearance

SOIL STRUCTURE

Calcareous .... Containing calcium carbonate

Slickensided ... The presence of planes of weakness having a slick and glossy appearance

Fissured ...... Breaks along definite planes of fracture with little resistance to fracturing

Laminated .... Alternating thin layers or lenses of varying material or color

Interbedded ... Alternating layers of varying material

* RQD is defined as the sum of the lengths of all core pieces 4 inches or longer, divided by the length of the core run. Core less than 4 inches in length broken by handling or the drilling process should be fitted together and counted in the RQD determination. If it is uncertain as to the nature of the break, the particular piece should not be counted.

LOG 01

Project: 620 @ MANSFIELD DAM

Location: ABOVE NAILED WALL **Date:** 6-6-95 **Type:** NX-CORE DIAMOND BIT **Boring No:** 1

DEPTH FEET	SYMBOL	SAMPLE	TEST RESULTS	MATERIAL DESCRIPTION	FORMATION	ROCK CORE REC./RQD %	ELEV.	DEPTH
							851.54	
0				SANDY LEAN CLAY; WITH WEATHERED LIMESTONE FRAGMENTS	GLEN ROSE			
				WEATHERED LIMESTONE; TAN, FRACTURED, BURROWED		100/0		
						27/0		
5						96/40		
			S 97%					
			S 97% UCS 4381 psi			100/58		
			UCS 703 psi					
10				LIMESTONE; GRAY, BURROWED, FOSSILIFEROUS, WITHY MARLY LAYERS AS SHOWN		100/94		
			UCS 1608 psi	DISCONTINUITY: 75°, tight, rough, undulating, no filling				
15						100/94		
20				9 in. marly layer				
			S 50% UCS 126 psi			100/94		
			UCS 1306 psi UCS 1071 psi					
25								
30						100/95		
			UCS 1139 psi UCS 2294 psi			100/100		
35				BOTTOM OF WALL			816.2	
						100/86		
40								

T.D. = 40.0'

BORING WAS ADVANCED TO 1.4 FEET PRIOR TO USING DRILLING FLUID TO ADVANCE THE HOLE AND GROUNDWATER WAS NOT OBSERVED ABOVE THAT DEPTH.

LOG O

Project: 620 @ MANSFIELD DAM

Location: ABOVE FRESH CUT **Date:** 6/6/95 **Type:** NX ROTARY CORE DIAMOND BIT **Boring No:** 2

DEPTH FEET	SYMBOL	SAMPLE	TEST RESULTS	MATERIAL DESCRIPTION	FORMATION	ROCK CORE REC./RQD %	ELEV.
							846.6'
				ASPHALT + BASE MATERIAL			
				SANDY CLAY; brown			
			UCS 1791 psi	5 in. thick marly layer		68/26	
5				WEATHERED LIMESTONE; TAN, FRACTURED BURROWED, WITH MARLY SEAMS AND LAYERS			
			UCS 1992 psi UCS 1751 psi			76/60	
10							
				LIMESTONE: GRAY, FINE GRAINED, BURROWED, FOSSILIFEROUS, WITH MARLY LAYERS AS SHOWN	GLEN ROSE	100/65	
15							
			S 51 %	1 ft. marly layer		100/60	
20							
			S 95 % UCS 1892 psi			100/83	
			S 88 %				
25							
						100/93	
30							
				BOTTOM OF CUT		100/83	814.0
35							
				8 in. marly layer		100/97	
40							806.6
				T.D. = 40.0' BORING WAS ADVANCED TO A DEPTH OF 2.7 FEET BEFORE USING DRILLING FLUID AND NO GROUNDWATER WAS OBSERVED ABOVE THAT DEPTH.			

LOG O

Project: IH 30 @ HAMPTON ROAD

Location: 160'N, 51'E OF CUT **Date:** 6-14-95 **Type:** NX-CORE **Boring No:** 1

DEPTH FEET	SYMBOL	SAMPLE	TEST RESULTS	MATERIAL DESCRIPTION	FORMATION	ROCK CORE REC./RQD %	ELEV.	DEPTH
				WEATHERED LIMESTONE (CHALK); tan : gray	AUSTIN CHALK	79/0		
5				D: 0°, smooth, tight, stained				
				3 D's: 0°, planar, smooth, tight, stained		100/85		
				D: 0°, planar, smooth, tight, stained				
10			S 94% UCS 1333 psi UCS 613 psi	D: 80°, undulating, v. rough, < 5mm aperture, stained				
						86/10		
15						96/8		
				D: 60°, undulating, v. rough, tight, stained				
20			UCS 1658 psi UCS 1791 psi	CHANGED FROM CARBIDE TO DIAMOND BIT		100/94		
25				D: 45°, undulating, rough, tight, stained — EST. BOTTOM OF CUT				
						100/97		
30			UCS 1021 psi			100/100		
35								
				LIMESTONE (CHALK); gray		100/100		
				SHALE, gray	EAGLE FORD			
40				T.D. = 39.7' BORING WAS ADVANCED TO 0.2' PRIOR TO USING DRILLING FLUID TO ADVANCE THE HOLE AND GROUNDWATER WAS NOT OBSERVED ABOVE THAT DEPTH.				

LOG O

Project: IH 30 @ HAMPTON ROAD

Location: 160' S, 25' E OF CUT **Date:** 6/15/95 **Type:** NX - CORE DIAMOND BIT **Boring No:**

DEPTH FEET	SYMBOL	SAMPLE	TEST RESULTS	MATERIAL DESCRIPTION	FORMATION	ROCK CORE REC./RQD %	ELEV.
0				CLAY; brown with weathered limestone fragments	AUSTIN CHALK		
				WEATHERED LIMESTONE(CHALK); tan, with marly seams as shown		80/0	
			UCS 1641 psi			100/65	
5			UCS 1574 psi	- 2DS: 0°, undulating, v. rough, tight, stained - DS: " " " " " - 2DS: " " " " "		100/56	
			UCS 870 psi				
10				- 2" MARLY SEAM - 2DS: " " " " " - DS: 60°, undulating, rough, tight, stained - DS: 20°, " " " " - 3DS: 0°, " " " " - 3DS: " " " " " 12 DS/Ft		100/68	
15			UCS 2578 psi	LIMESTONE(CHALK); gray		100/91	
20				- DS: 0°, undulating, very rough, tight, stained		100/88	
			UCS 251 psi				
25				- DS: 75°-80°, undulating, v. rough, 1mm iron coating, aperture unknown EST. BOTTOM OF CUT		96/80	
30						100/89	
35						100/100	
						98/100	
40				T.D. = 40.0' BORING WAS ADVANCED TO 1.4 FEET PRIOR TO USING DRILLING FLUID AND GROUNDWATER WAS NOT OBSERVED ABOVE THAT DEPTH.			

LOG O!

Project: LOOP 1604 @ BITTERS ROAD

Location: 50'W AND 20'N OF CUT **Date:** 6-8-95 **Type:** NX CORE D; AMOND BIT **Boring No:** 1

DEPTH FEET	SYMBOL	SAMPLE	TEST RESULTS	MATERIAL DESCRIPTION	FORMATION	ROCK CORE REC./RQD %	ELEV.	DEPTH
0–5			UCS 2076 psi	WEATHERED LIMESTONE; tan 100% WATER LOSS 0'-5': HIGHLY FRACTURED (2"-4" PIECES), HARD, FINE TEXTURE, SLIGHTLY VUGGY (1)	EDWARDS	90/26		
5–10				5'-8': HIGHLY FRACTURED (½"-3" PIECES), COARSE TEXTURED, FOSSILIFEROUS (2) 8'-10': (1)		86/10 80/0		
10–15						31/0 38/0		
15–20						23/0		
20–25				10'-24': (2)		31/0 100/36		
25–30			UCS 2545 psi	DISCONTINUITY: 60°-70°, Rough, Undulating, tight, no filling D: 75°, Rough, undulating, stained, tight, no filling CHERT EST. BOTTOM OF CUT		100/37 63/0		
30–35						34/0		
35–40				24'-40': (1)		21/0 20/0		

T.D. = 40.0'

LOG O

Project: LOOP 1604 @ BITTERS ROAD

Location: 26' S AND 30' W OF CUT **Date:** 6-8-95 **Type:** NX-CORE DIAMOND BIT **Boring No:** 2

DEPTH FEET	TEST RESULTS	MATERIAL DESCRIPTION	FORMATION	ROCK CORE REC./RQD %	ELEV.
0		SANDY CLAY; brown			
		WEATHERED LIMESTONE; tan & light gray	EDWARDS	100/33	
3	UCS 4709 psi				
5		D: 60°-75°, planar, slickensided, tite, stained, thin coating of clay			
		CLAY SEAM OR POCKET		69/0	
10		0.5'-12': HIGHLY FRACTURED (1"-4" PIECES), STAINED, PORCELAINIC, OCC. SMALL VUGS			
	UCS 2528 psi				
	UCS 6379 psi	D: 45°-60°, undulating, slickensided, tite, unweathered		100/42	
15		12'-15.5': MIXED WITH DK. BROWN CHERT		100/57	
		16.5'-17.5': COARSE TEXTURED, SM. VUGS, SHELL FRAGS			
		very vuggy		100/0	
20				95/25	
	UCS 3499 psi	50% WATER LOSS		100/0	
25				100/0	
				50/0	
				50/0	
				50/0	
				100/0	
				100/0	
30		D: 90°, undulating, slickensided, tite, no filling / EST. BOTTOM OF CUT		87/0	
				80/0	
				100/0	
	UCS 8137 psi	17.5'-40.0': HARD, TAN & GRAY, PORCELAINIC, HIGHLY FRACTURED, SOLUTIONED		50/0	
35				50/0	
				100/0	
				100/0	
				100/0	
40		T.D. = 40.0'			

APPENDIX D

Laboratory Test Results

Table D.3. Laboratory Test Results for San Antonio District Sites.

Site Code	Sample Identification[1]	Formation	Description	Depth (m)	Field-observed Erodibility [2]	Water content (%)	Carbonate content (%)	Second cycle slake durability (%)	Uniaxial compressive strength (MPa)	E from P-wave testing (MPa)	E_secant (MPa)[1]	E_tangent at 50% of ultimate strength (MPa)	Splitting tensile strength (MPa)	Hardness on Moh's scale
281-3	281-3_H	Glen Rose	Light grey, hard Limestone	N/AP	NE	0.9	100	97	N/AV	N/AV	N/AV	N/AV	N/AV	2 to 3
281-3	281-3_Marl_E	Glen Rose	Grey Marl	N/AP	E	2.5	68	68	N/AV	N/AV	N/AV	N/AV	N/AV	1 to 2
281-4	281-4_Marl_E	Glen Rose	Tan, marly Limestone	N/AP	E	8.6	78	47	N/AV	N/AV	N/AV	N/AV	N/AV	1 to 2
I-10-1	I-10-1_S-1	Fort Terret / Glen Rose	Grey / light grey Limestone	N/AP	E	2.1	80	95	N/AV	N/AV	N/AV	N/AV	N/AV	2 to 3
I-10-3	I-10-3_S-1	Fort Terret/ Glen Rose	Tan / yellow, clayey Dolomite	N/AP	E	5.4	94	32	N/AV	N/AV	N/AV	N/AV	N/AV	1 to 2
I-10-4	I-10-4_S-1	Fort Terret/ Glen Rose	Soft, light tan Dolomite	N/AP	E	6.0	99	78	N/AV	N/AV	N/AV	N/AV	N/AV	1 to 2
I-10-5	I-10-5_S-1	Glen Rose	Tan, medium hardness Limestone	N/AP	E	2.0	82	63	N/AV	N/AV	N/AV	N/AV	N/AV	1 to 2
470-1	470-1 W_MARL_1	Fort Terret/ Glen Rose	Light tan, highly weathered crumbly Marl	N/AP	E	3.0	82	40	N/AV	N/AV	N/AV	N/AV	N/AV	1 to 2
470-1	470-1_F_MARL_1	Fort Terret/ Glen Rose	Dark tan, clayey Marl	N/AP	E	8.7	84	58	N/AV	N/AV	N/AV	N/AV	N/AV	1 to 2
470-1 [3]	470-1_MR	Fort Terret/ Glen Rose	Light tan to white, hard Limestone	N/AP	NE	0.5	100	97	N/AV	N/AV	N/AV	N/AV	N/AV	2 to 3
S-1	B-1 C1	Edwards Limestone	Tan, hard Limestone	1.07 -1.34	N/AP	6.7	87	N/AV	34.31	N/AV	2813	3610	2.17	2 to 3
S-1	B-1 C6	Edwards Limestone	Grey, hard Limestone	7.92 -8.1	N/AP	3.4	89	N/AV	17.55	N/AV	2564	3024	N/AV	2 to 3
S-1	B-2 C5	Edwards Limestone	Tan, hard Limestone	0.76 - 0.88	N/AP	5.9	96	N/AV	32.44	N/AV	4325	4992	N/AV	2 to 3
S-1	B-2 C6	Edwards Limestone	Grey, hard Limestone	3.5 - 3.66	N/AP	2.7	94	N/AV	17.43	N/AV	2869	4309	1.85	3 to 4
S-1	B-2 C7	Edwards Limestone	Grey, hard Limestone	3.93 - 4.08	N/AP	3.1	84	N/AV	43.98	N/AV	10390	12536	N/AV	3 to 4
S-1	B-2 C13	Edwards Limestone	Grey, hard Limestone	6.76 -6.92	N/AP	6.6	89	N/AV	34.13	N/AV	6633	10055	N/AV	3
S-1	B-2 C15	Edwards Limestone	Grey, hard Limestone	10.48 -10.61	N/AP	4.9	90	N/AV	56.10	N/AV	N/AV	N/AV	N/AV	

[1] B1 = sample obtained from bore hole 1; B2 = sample obtained from bore hole 2.

[2] Key: E = Erodible; NE = Non-erodible; H = Hard; MR = More resistant to erosion; LR = Less resistant to erosion; W = Weathered; (?) = missing data; N/AP = Not applicable; N/AV= Information not available

[3] Sample obtained from lower 6.1 m.

Table D.2. Laboratory Test Results for Dallas and Fort Worth District Sites.

Site Code	Sample identification[1]	Formation	Description	Color code[2]	Depth (m)	Field-observed Erodibility[3]	Water content (%)	Carbonate content (%)	Second cycle slake durability (%)	Uniaxial compressive strength (MPa)	E from P-wave testing (MPa)	E_secant (MPa)[3]	E_tangent at 50% of ultimate strength (MPa)	Splitting tensile strength (MPa)	Hardness on Moh's scale
D-2	B1 C4	Austin Chalk	Tan Chalk	1	2.74 - 3.05	NE	15.0	85	94	9.19	N/AV	756	1446	1.25	1 to 2
D-2	B1 C5	Austin Chalk	Tan Chalk	1	3.05 - 3.3	NE	16.7	72	N/AV	4.23	N/AV	330	427	1.14	1 to 2
D-2	B1 C7	Austin Chalk	1/2 tan, 1/2 grey Chalk	1,3	6.03 - 6.25	NE	15.3	92	N/AV	11.43	N/AV	1612	2738	0.30	1 to 2
D-2	B1 C8	Austin Chalk	Grey Chalk	4	6.25 - 6.55	NE	13.5	89	N/AV	12.01	N/AV	1304	1465	1.39	2 to 3
D-2	B1 C17	Austin Chalk	Grey Chalk	5	9.05 - 9.48	NE	11.7	79	96	7.04	N/AV	695	N/AV	1.66	2 to 3
D-2	B2 C7	Austin Chalk	Tan Chalk	1	1.16 - 1.40	NE	13.6	90	N/AV	11.31	N/AV	1228	1902	1.18	2 to 3
D-2	B2 C4	Austin Chalk	Tan Chalk	1	1.77 - 1.92	NE	14.5	80	N/AV	10.85	N/AV	1240	2721	0.94	1 to 2
D-2	B2 C6	Austin Chalk	Tan Chalk	1	2.22 - 2.41	NE	14.4	82	N/AV	8.00	N/AV	N/AV	N/AV	N/AV	1 to 2
D-2	B2 C12	Austin Chalk	Grey Chalk	3	5.06 - 5.30	NE	10.5	87	N/AV	17.78	N/AV	1755	2428	1.39	2 to 3
D-2	B2 C20	Austin Chalk	Grey Chalk	5	7.16 - 7.37	NE	12.5	87	N/AV	1.71	N/AV	N/AV	N/AV	N/AV	1 to 2

[1] B1 = sample from bore hole 1; B2 = sample from bore hole 2.
[2]Color codes for Austin Chalk are assigned as follows:
1: white; 2: light dark; 3: mixed grey and dark; 4: dark; 5: very dark.
(Olson et al, 1991)

Table D.1. Laboratory Test Results for Austin District Sites.

Site Code	Sample identification[1]	Formation	Description	Depth (m)	Field-observed Erodibility*	Water content (%)	Carbonate content (%)	Second cycle slake durability (%)	Uniaxial compressive strength (MPa)	E from P-wave testing (MPa)	E_secant (MPa)*	E_tangent at 50% of ultimate strength (MPa)	Splitting tensile strength (MPa)	Hardness on Moh's scale
360-1	360 CASE STUDY SITE_INE	Glen Rose	White / light grey, hard Limestone	N/AP	NE	7.8	100	97	N/AV	N/AV	N/AV	N/AV	N/AV	2 to 3
360-1	360 CASE STUDY SITE_IE	Glen Rose	Grey, soft Marl	N/AP	E	7.0	82	85	N/AV	N/AV	N/AV	N/AV	N/AV	1 to 2
360-2	360-2_1_E	Glen Rose/Edwards/ Walnut formation	Grey Marl	N/AP	E	4.9	84	75	N/AV	N/AV	N/AV	N/AV	N/AV	2 to 3
620-1	FM 620_N_1_MR	Glen Rose	Grey, hard Limestone	N/AP	NE	2.2	92	93	N/AV	N/AV	N/AV	N/AV	N/AV	2 to 3
620-1[2]	FM 620_N_2_LR	Glen Rose	Dark grey, fossiliferous marly Limestone	N/AP	E		62	73	N/AV	N/AV	N/AV	N/AV	N/AV	2 to 3
620-1	B-1 C5	Glen Rose	Tan, hard Limestone	2.13 - 2.25	NE	12.4	89	97	N/AV	N/AV	N/AV	N/AV	N/AV	2 to 3
620-1	B 1 C6	Glen Rose	Tan, hard, Limestone	2.44 - 2.65	NE	6.6	100	97	30.20	17173	4890	4886	N/AV	2 to 3
620-1	B-1 C7	Glen Rose	Tan Limestone	2.65 -2.83	NE	6.5	92	N/AV	N/AV	8028	N/AV	N/AV	N/AV	2 to 3
620-1	B-1 C8	Glen Rose	Tan Limestone	2.83 -2.95	NE	6.8	87	N/AV	4.85	7061	354	338	N/AV	2 to 3
620-1	B 1 C13	Glen Rose	Hard, grey Limestone	4.14 -4.45	NE	7.2	94	N/AV	11.08	15658	1238	2996	N/AV	2 to 3
620-1	B1 C20	Glen Rose	Marly, dark grey, Limestone	6.22 -6.43	E	9	63	50	0.87	705	21.10	35.85	N/AV	1 to 2
620-1	B-1 C22A	Glen Rose	Grey Limestone	7.01 - 7.25	NE	6.1	87	N/AV	9.00	6854	823	2241	N/AV	2 to 3
620-1	B-1 C22B	Glen Rose	Grey Limestone	7.01 - 7.25	NE	6.4	84	N/AV	7.39	17175	732	3991	N/AV	2 to 3
620-1	B-1 C29A	Glen Rose	Grey Limestone	12.15 -10.21	NE	6.7	77	N/AV	7.85	N/AV	738	1011	N/AV	2 to 3
620-1	B-1 C29B	Glen Rose	Grey Limestone	12.15 -10.21	NE	6.3	89	N/AV	15.81	N/AV	2001	2281	N/AV	2 to 3
620-1	B 2 C4	Glen Rose	Tan, hard, Limestone	1.04 -1.16	E	4.6	100	N/AV	12.35	28112	5043	6153	N/AV	2 to 3
620-1	B-2 C5A	Glen Rose	Tan Limestone	2.25 - 2.53	NE	6.5	82	N/AV	13.74	16972	1809	2934	N/AV	2 to 3
620-1	B-2 C5B	Glen Rose	Tan Limestone	2.25 - 2.53	NE	6.6	97	N/AV	12.07	19215	1589	2859	N/AV	2 to 3
620-1	B-2 C6	Glen Rose	Tan Limestone	2.65 -2.80	NE	8.8	80	N/AV	N/AV	10650	N/AV	N/AV	N/AV	2 to 3
620-1	B-2 C 15	Glen Rose	Grey, marly, limestone	4.72 -5.39	E	8.9	75	51	N/AV	N/AV	N/AV	N/AV	N/AV	2 to 3
620-1	B 2 C 20	Glen Rose	Hard, dark grey Limestone	6.7 - 6.92	NE	6.9	97	95	13.04	N/AV	2862	3117	N/AV	2 to 3
620-1	B-2 C20	Glen Rose	Grey Limestone	6.7 - 6.92	NE	N/AV	N/AV	N/AV	N/AV	17556	N/AV	N/AV	N/AV	N/AV
620-1	B-2 C20	Glen Rose	Grey Limestone	6.7 - 6.92	NE	N/AV	N/AV	N/AV	N/AV	7811	N/AV	N/AV	N/AV	
620-1	B-2 C23	Glen Rose	Grey, hard, Limestone	7.25 -7.53	NE	7.2	80	88	N/AV	N/AV	N/AV	N/AV	N/AV	
2244-1	2244-1_S-1	Glen Rose	Tan, medium hardness Limestone	N/AP	E	1.0	92	89	N/AV	N/AV	N/AV	N/AV	N/AV	
2244-2	2244-2_S-1	Glen Rose	Greyish tan Limestone	N/AP	NE	2.9	89	93	N/AV	N/AV	N/AV	N/AV	N/AV	
2244-2	2244-2_S-2	Glen Rose	Dark grey with some tan, very clayey Limestone	N/AP	E	7.8	85	87	N/AV	N/AV	N/AV	N/AV	N/AV	
SWP-1	SWP1_S1	Glen Rose	Grey, medium hard Limestone with fossil shells	N/AP	E	4.8	N/AV	91	N/AV	N/AV	N/AV	N/AV	N/AV	
SWP-1	SWP1_S2	Glen Rose	Tan, medium hard Limestone	N/AP	E	2.0	N/AV	88	N/AV	N/AV	N/AV	N/AV	N/AV	
SWP-1	SWP1_S3	Glen Rose	Tan, medium hardness Limestone	N/AP	?	1.3	92	90	N/AV	N/AV	N/AV	N/AV	N/AV	
Au-2	2222 @ 360_E	Glen Rose	Dark grey, very soft Marl	N/AP	E	10.8	68	41	N/AV	N/AV	N/AV	N/AV	N/AV	
Au-2	2222 @ 360_H	Glen Rose	Light tan Limestone	N/AP	NE	0.5	92	98	N/AV	N/AV	N/AV	N/AV	N/AV	

[1]B1 = sample obtained from bore hole 1; B2 = sample obtained from bore hole 2.

* Key: E = Erodible; NE = Non-erodible; H = Hard; MR = More resistant to erosion; LR = Less resistant to erosion; W = Weathered; (?) = missing data; N/AP = Not applicable; N/AV= Information not available.

APPENDIX E

Performance Data Analysis

Appendix E

This appendix contains detailed engineering geologic data utilized for this project. Plots were made of the potential factors affecting performance vs. the performance measures (e.g. Maintenance *Rating*, Visual *Stability Rating*, and *Degree of* Differential Erosion). Several of the variables were normalized by age because it was initially thought that some of these factors would be influenced by the slope age (e.g. degree of differential erosion). Due to the geologic variability among sites, however, age did not appear to influence the relationships. Also included in this Appendix are summary tables of the RMR and SMR determinations. Histograms of certain variables are included to show the distribution of certain factors such as: age, height RQD, SMR, and RMR.

Table E.1 Pertinent Data for Glen Rose Sites

SITE	H (m)[a]	AGE (Y)	Δ SLAKE	SEEPAGE	SLOPE ORIENTATION	DDE	AVG. RQD	VSR	MR	Avg. RMR	Avg. SMR
360-1	22.5[a]	10	12	YES	180	2	70	1	2	69.5	75
360-3	6.6	18		NO	235	0	80	3.5	3	66	74.5
620-1	10.5	1	22	YES	270	0	54	4	3	75	67.2
620-2	9[a]	7		NO	155	0	70	3	3	71	71
2244-1	6.6	7	3	NO	240	0	67.5	3	3	62	72
2244-2	5.4	7	5	YES	250	1	82.5	2	3	71	77.6
SWP-1	7.5	8	8	NO	180	0.5	77.5	3	3	71	81
SRR-1	9	6.5		YES	265	2	62.5	2.5	0	58.5	54.5
AU-1	>15	22.5		NO		1		2	0		
AU-2	7.5	5.5	56	YES	50	2	67.5	1	0		
281-1	6	32		YES	165	2	62.5	1	2	58	58
281-2	7.5	32		NO	0	0	63	2	3	68	66
281-3	10.5	32	29	YES	190	2	70	2	0.5	60	69
281-4	4.5	32	48	NO	180	0	65	2	1	65	49
281-5	9	32		NO	200	0	95	3	1	67	57
1376-1	13.5	40		YES	0	0	50	0.5	0.5	46	44
1376-2	9	40		NO	356	0	70	0.5	0	67	50
I-10-5	7.5	26	32	NO	160	2	62.5	1	3	67	68
2722-1	10.5[a]	15		NO	168	0	62.5	4	2	62	12
2673-1	7.5	25		NO	90	1	62.5	0.5	2	56	56
1263-1	15	19		NO	195	0	65	3	3	72	73
Mean	***9.2***	***19.8***				***0.7***	***69.5***	***2.1***	***1.8***	***64.8***	***61.7***
std. dev.	***4.6***	***12.5***				***0.9***	***10.1***	***1.1***	***1.2***	***7.0***	***16.0***
covar.	***48.5***	***62.9***				***120.5***	***14.6***	***53.8***	***68.5***	***10.8***	***25.9***

Notes: [a] indicates height of slope or lowest bench for benched cuts, DDE = Degree of Differential Erosion, VSR = Visual Stability Rating, MR = Maintenance Rating, covar. = coefficient of variation

Table E.2 Pertinent Data for Edwards Sites

SITE	H (m)[a]	AGE (Y)	SEEPAGE	SLOPE ORIENTATION	DDE	AVG. RQD	VSR	MR	Avg. RMR	Avg. SMR
AU-3	14	22	NO		0	57.5			61	53
AU-4	12	42.5	NO	145	0	70		3	68	68
3159-1	6	17.5	NO	225	0	90	4	2.5	76	66
I-10-2	7.5	25	NO	100	0	80	3	2	66	69
I-10-6	21	25	NO	270	0	85	4	3	76	77
I-10-7	5.5	25	NO	120	0	60	4	3	76	84
I-10-9	7.5	25	NO	285	0	20	3	3	55	65
41-1	10.5	27.5	NO	255	0	70	2	2	65	63
187-1	15	30	NO	40	0	92.5	3.5	3	88	98
337-2	7.5	20	NO	90	0	77.5	3	1	76	75
211-1	6[a]	3	NO	25	0	30	2	3	62	70
211-2	6[a]	3	NO	235	0	40.5	2.5	3	65	74
211-3	5.1[a]	3	YES	140	0	60	2.5	2	73	74
1283-2	10.5	19	NO	0	0	75	3	2	72	75
173-1	15	30	NO	350	0	75	3.5	3	74	74
S-1	8	10	NO	222	0	25	3.5	2	66	66
S-2	5.5	1	NO		0	60	4	3	62	62
mean	***9.6***	***19.3***				***64.0***	***3.2***	***2.6***	***69.4***	***71.1***
std. dev	***4.6***	***11.7***				***22.6***	***0.7***	***0.6***	***7.9***	***9.6***
covar.	***47.0***	***60.6***				***35.3***	***22.1***	***24.4***	***11.3***	***13.7***

Notes: [a] indicates height of slope or lowest bench for benched cuts, DDE = Degree of Differential Erosion, VSR = Visual Stability Rating, MR = Maintenance Rating, covar. = coefficient of variation

Table E.3 Pertinent Data for Sites Where Edwards is Exposed over Glen Rose

SITE	H (m)[b]	AGE (Y)	Δ SLAKE	SEEPAGE	SLOPE ORIENTATION	DDE	AVG. RQD	VSR	MR	Avg. RMR	Avg. SMR
I-10-1	6.6[a]	25	5	yes	180	2	82.5	4	2	77	85
I-10-3	5.4[a]	25	63	yes	90	2	37.5	1	2	66	65
I-10-4	16.5	25	22	no	270	1	82.5	3	2	80	89
I-10-8	24	25		yes	280	2	95	3	1	82	67
337-1	18	20		yes	90	1	80	1.5	0	68	70
470-1	16.5	30	42	yes	240	2	46.5	0.5	2	56	56
mean	***14.5***	***25.0***				***1.7***	***70.7***	***2.2***	***1.5***	***71.3***	***71.6***
stdev	***7.2***	***3.2***				***0.5***	***23.0***	***1.4***	***0.8***	***10.0***	***12.6***
covar	***49.3***	***12.6***				***31.0***	***32.5***	***63.1***	***55.8***	***14.0***	***17.6***

Notes: [a] indicates height of slope or lowest bench for benched cuts, DDE = Degree of Differential Erosion, VSR = Visual Stability Rating, MR = Maintenance Rating, covar. = coefficient of variation

Table E.4 Rock Mass Rating (Bieniawski, 1973)

Parameter	Range of Values						
UCS (MPa)	>250	100-250	50-100	25-50	5-25	1-5	<1
Rating	*15*	*12*	*7*	*4*	2	*1*	*0*
RQD	90-100		50-75	25-50	<25		
Rating	*20*	*17*	*13*	*8*	*3*		
Spacing of Discontinuities	>2m	0.6-2m	200-600 mm	60-200 mm	< 60 mm		
Rating	*20*	*15*	*10*	*8*	*5*		
Condition of Discontinuities	V. rough surfaces, not continuos, No separation, unweathered wall rock	Slightly rough surfaces, separation < 1 mm, slightly weathered walls	Slightly rough surfaces, separation < 1 mm, highly weathered walls	Slickensided surfaces, or gouge < 5 mm thick, or separation 1-5 mm, continuous	Soft gouge > 5 mm thick, or separation > 5 mm thick, continuous		
Rating	*30*	*25*	*20*	*10*	*0*		
Groundwater in joints	Completely Dry	Damp	Wet	Dripping	Flowing		
Rating	*15*	*10*	*7*	*4*	*0*		
Strike and dip orientations of discontinuities	*Very Unfavorable*	*Favorable*	*Fair*	*Unfavorable*	*Very Unfavorable*		
Rating — Tunnels	0	-2	-5	-10	-12		
Rating — Foundations	0	-2	-7	-15	-25		
Rating — Slopes	0	-5	-25	-50	-60		

Notes: UCS = uniaxial compressive strength, RQD = Rock Quality Designation (Deere, 1963)

$$SMR = RMR + (F1*F2*F3) + F4 \qquad (1)$$

Table E.5 Joint Adjustment Ratings for SMR Classification (Romana, 1993)

Case	Very Favorable	Favorable	Fair	Unfavorable	Very Unfavorable
P $\lvert\alpha_j - \alpha_s\rvert$	$> 30^\circ$	$30\text{-}20^\circ$	$20\text{-}10^\circ$	$10\text{-}5^\circ$	$< 5^\circ$
T $\lvert(\alpha_j - \alpha_s) - 180\rvert$					
P/T *F1*	0.15	0.40	0.70	0.85	1.00
P $\lvert\beta_j\rvert$	< 20	$20\text{-}30^\circ$	$30\text{-}35^\circ$	$35\text{-}45^\circ$	$> 45^\circ$
P *F2*	0.15	0.40	0.70	0.85	1.00
T *F2*	1	1	1	1	1
P $\beta_j - \beta_s$	$> 10^\circ$	10-0	0°	0 to -10°	$< -10^\circ$
T $\beta_j + \beta_s$	$< 110^\circ$	$110\text{-}120^\circ$	$> 120^\circ$	—	—
P/T *F3*	0	-6	-25	-50	-60

Notes: P = planar failure, T = toppling failure, α_j = joint dip direction, α_s = slope dip direction, β_j = joint dip, β_s = slope dip

Table E.6 Adjustment Rating for Method of Excavation (Romana, 1993)

Method	Natural Slope	Pre-splitting	Smooth Blasting	Blasting or Mechanical	Deficient Blasting
F4	+15	+10	+8	0	-8

Table E.7 Summary of RMR and SMR Factors for Glen Rose Sites

Site	UCS	RQD	Js	Jc	Jw	RMR	F1	F2	F3	F4	SMR
360-1	2	15	20	23	9.5	70	0.18	1	-25	10	75
360-3	2	17	15	17	15	66	0.25	1	-6	10	75
620-1	2	18.5	20	23	11.5	75	0.13	1	-60	0	67
620-2	2	15	15	24	15	71	0.15	0.15	0	0	71
2244-1	2	17	15	21	7	62	0.15	0.15	0	10	72
2244-2	2	13	20	21	15	71	0.58	1	-6	10	78
SWP-1	2	15	15	24	15	71	0.15	0.15	0	10	81
SRR-1	2	13	15	19	9.5	59	0.28	1	-50	10	55
281-1	2	13	15	22	5.5	58	0.15	0.15	0	0	58
281-2	2	12.5	20	18	15	68	0.25	0.85	-60	10	65
281-3	2	13	20	21	4	60	0.25	1	-6	10	69
281-4	2	13	20	15	15	65	0.43	1	-60	10	49
281-5	2	20	20	10	15	67	0.33	1	-60	10	57
1376-1	2	10.5	12.5	14	7	46	0.28	1	-6	0	44
1376-2	2	15	15	20	15	67	0.68	1	-25	0	50
I-10-5	2	13	15	22	15	67	0.18	1	-60	10	66
2722-1	2	13	15	17	15	62	1	1	-60	10	12
2673-1	2	13	17	17	7	56	0.15	1	0	0	56
1283-1	2	13	20	22	15	72	0.15	1	-60	10	73
Mean	*2*	*14.3*	*17.1*	*19.5*	*11.9*	*64.8*	*0.3*	*0.8*	*-28.6*	*6.8*	*61.7*
Std. Dev.	*0*	*2.4*	*2.7*	*3.7*	*4.0*	*7.0*	*0.2*	*0.4*	*27.4*	*4.8*	*15.9*

Notes: Js = joint spacing, Jc = joint condition, Jw = joint water, F1-F3 relate to discontinuity orientations (see Tables E.4-E.6), F4 relates to method of construction.

Table E.8 Summary of RMR and SMR Factors for Edwards Sites

Site	UCS	RQD	Js	Jc	Jw	RMR	F1	F2	F3	F4	SMR
Au-3	6	13	11.5	15	15	**61**	0.15	0.15	0	-8	**53**
Au-4	2.5	15	15	20	15	**68**	0.15	0.15	0	0	**68**
3159-1	4	18.5	20	18	15	**76**	0.33	1	-60	10	**66**
I-10-2	4	10	15	22	15	**66**	0.15	1	-50	10	**69**
I-10-6	4	17	20	20	15	**76**	0.15	1	-60	10	**77**
I-10-7	4	17	20	20	15	**76**	0.4	1	-6	10	**84**
I-10-9	4	3	8	25	15	**55**	0.15	0.15	1	10	**65**
41-1	4	10.5	15	20	15	**65**	0.15	0.15	-60	0	**63**
187-1	4	18.5	20	30	15	**88**	0.15	0.15	0	10	**98**
337-2	4	17	18	22	15	**76**	0.43	1	-25	10	**75**
211-1	4	5.5	12.5	25	15	**62**	0.4	1	-6	10	**70**
211-2	4	10	13	23	15	**65**	0.15	1	-6	10	**74**
211-3	4	14	20	20	15	**73**	0.15	1	-60	10	**74**
1283-2	4	15	20	18	15	**72**	0.15	1	-50	10	**75**
173-1	4	15	10	30	15	**74**	0.115	0.15	0	0	**74**
S-1	4	14	15	20	15	**68**	0.15	0.15	0	0	**68**
S-2	5	12	10	20	15	**62**	0.15	0.15	0	0	**62**
Mean	***4.1***	***13.2***	***15.5***	***21.6***	***15.0***	***69.4***	***0.2***	***0.6***	***-22.5***	***6.0***	***71.3***
Std. Dev.	***0.7***	***4.4***	***4.2***	***4.0***	***0.0***	***7.9***	***0.1***	***0.4***	***26.9***	***5.9***	***9.8***

Notes: Js=joint spacing, Jc=joint condition, Jw=joint water, F1-F3 relate to discontinuity orientations (see Tables E.4-E.6), F4 relates to method of construction.

Table E.9 Summary of RMR and SMR Factors for Edwards over Glen Rose Sites

Site	UCS	RQD	Js	Jc	Jw	RMR	F1	F2	F3	F4	SMR
I-10-1	4	17	20	21	15	**77**	0.4	1	-6	10	**85**
I-10-3	3	8	15	25	15	**66**	0.15	0.15	-60	0	**65**
I-10-4	3	17	20	25	15	**80**	0.15	0.15	-60	10	**89**
I-10-8	3.5	20	20	23	15	**82**	1	1	-25	10	**67**
337-1	3	15	20	15	15	**68**	0.33	1	-25	10	**70**
470-1	2.5	10	17	19	7	**56**	0.15	1	0	0	**56**
Mean	***3.2***	***14.5***	***18.7***	***21.3***	***13.7***	***71.3***	***0.4***	***0.7***	***-29.3***	***6.7***	***71.6***
Std. Dev.	***0.5***	***4.6***	***2.2***	***3.9***	***3.3***	***10.0***	***0.3***	***0.4***	***25.8***	***5.2***	***12.6***

Notes: Js=joint spacing, Jc=joint condition, Jw=joint water, F1-F3 relate to discontinuity orientations (see Tables E.4-E.6), F4 relates to method of construction.

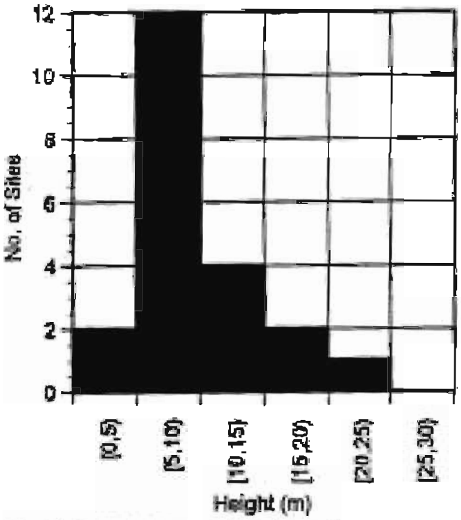


Fig. E.1 Height distribution of Glen Rose sites.

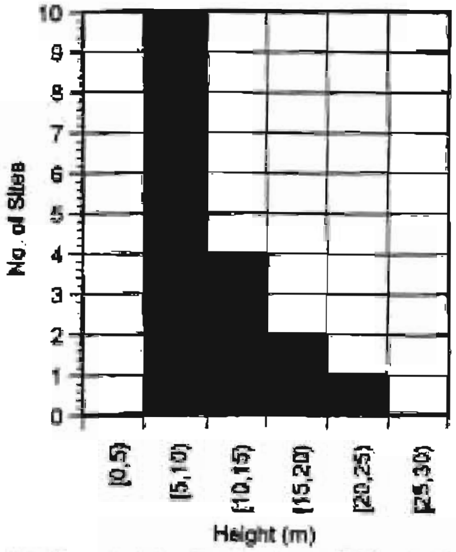


Fig. E.2 Height distribution of Edwards sites

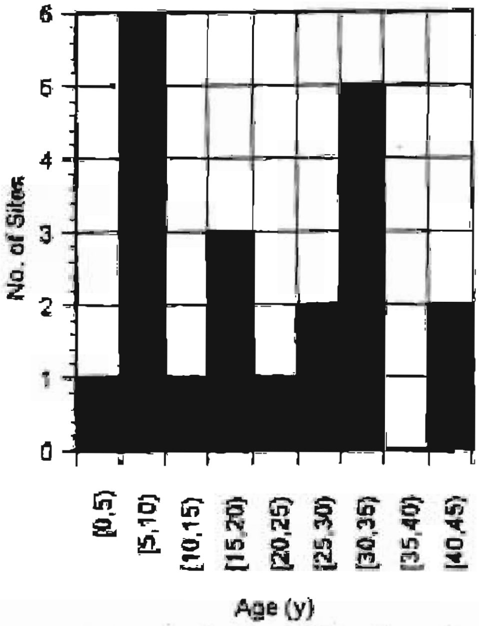


Fig. E.3 Age distribution of Glen Rose sites.

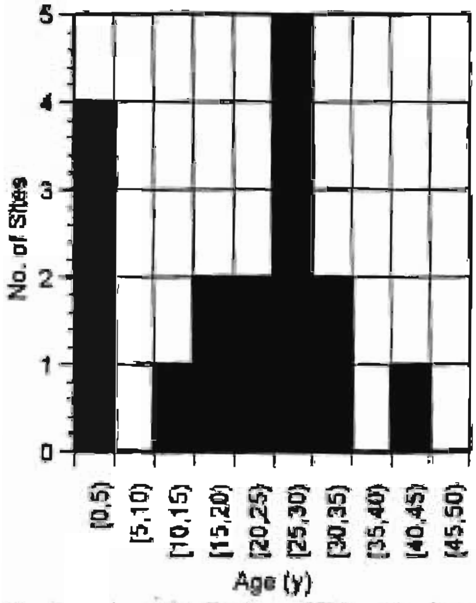


Fig. E.4 Age distribution of Edwards sites.

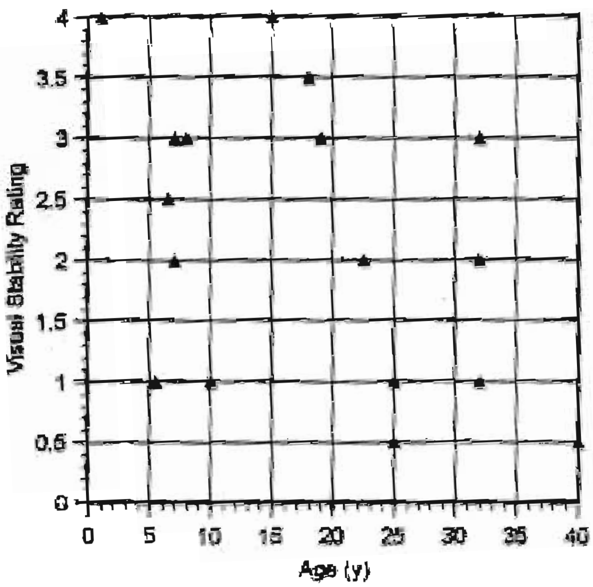


Fig. E.5 VSR vs. age for Glen Rose sites. Increasing VSR values indicate increased performance.

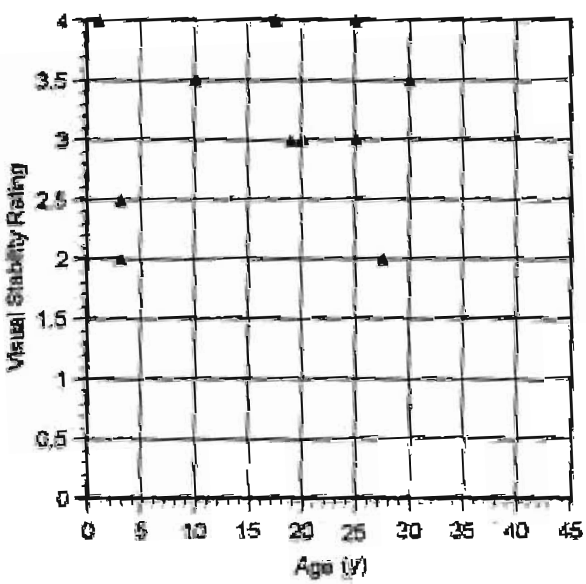


Fig. E.6 VSR vs. age for Edwards sites.

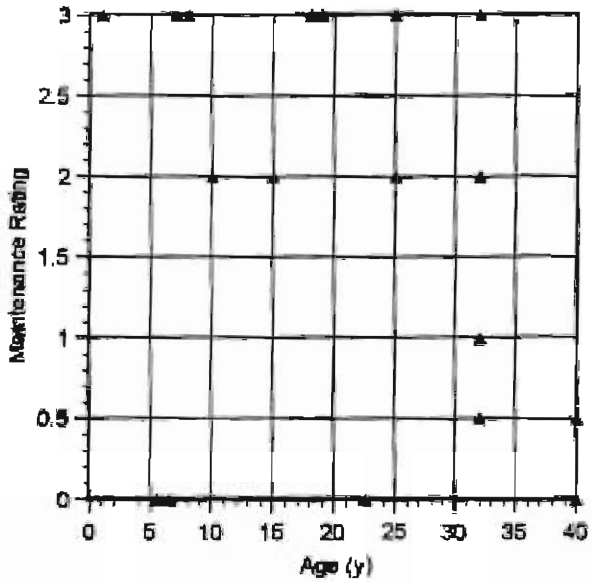


Fig. E.7 MR vs. age for Glen Rose sites. Note, increasing MR indicates decreasing maintenance frequency.

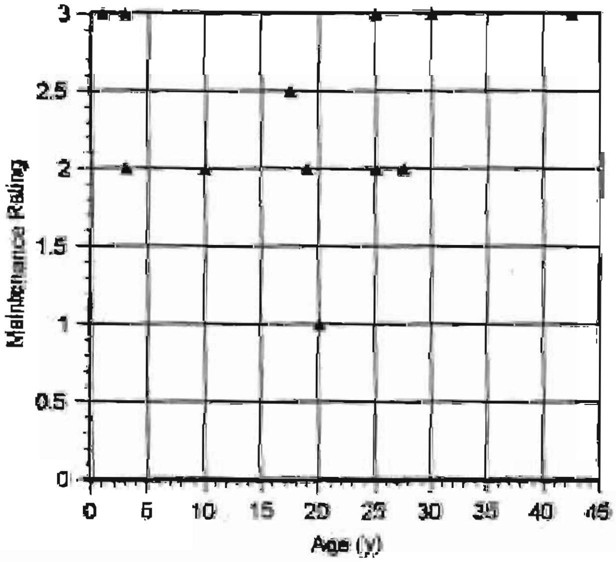


Fig. E.8 MR vs. age for Edwards sites. Note, increasing MR indicates decreasing maintenance frequency.

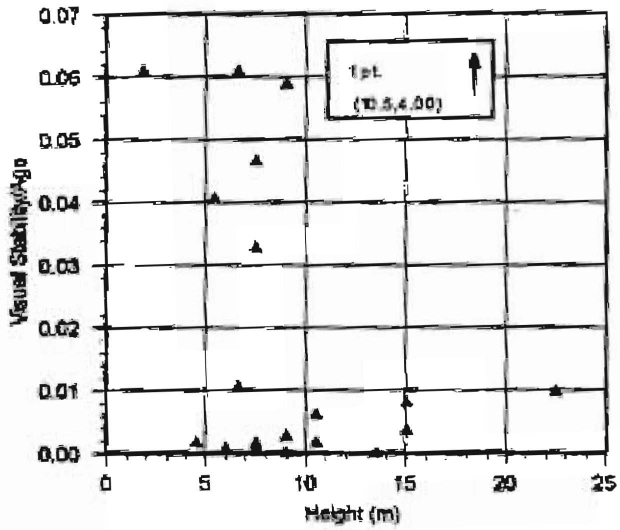


Fig E. 9 VSR normalized by age vs. height for Glen Rose sites. Increasing VSR values indicate increased performance.

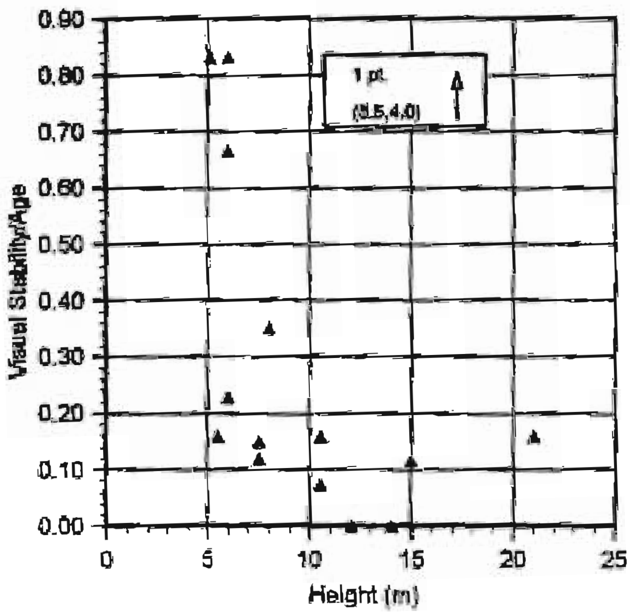


Fig. E.10 VSR normalized by age vs. height for Edwards sites. Note that stability increases with increasing VSR.

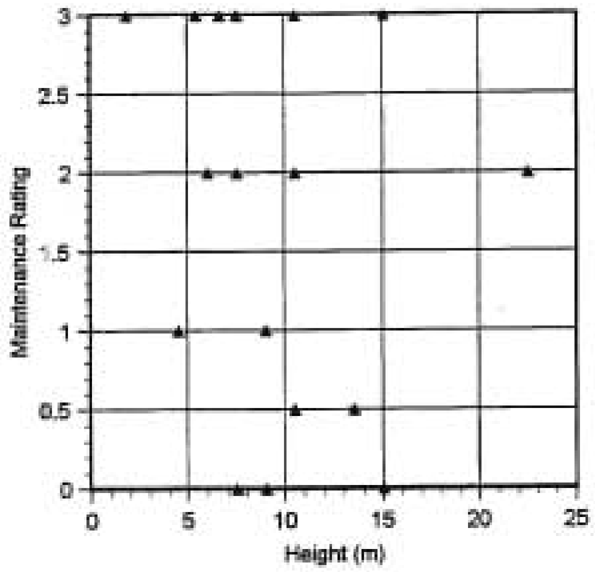


Fig. E.11 MR vs. height for Glen Rose sites. Note, increasing MR indicates decreasing maintenance frequency.

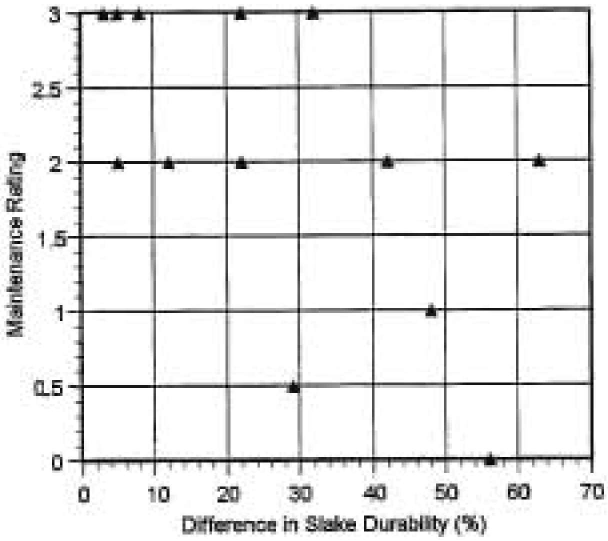


Fig. E.12 MR vs. difference in slake durability. Includes Glen Rose and Edwards over glen Rose sites.

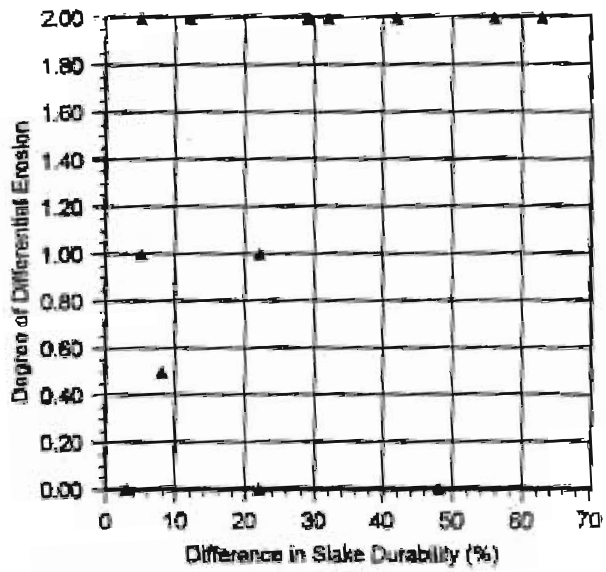


Fig. E.13 DDE vs. difference in slake durability. Includes Glen Rose and Edwards over Glen Rose sites.

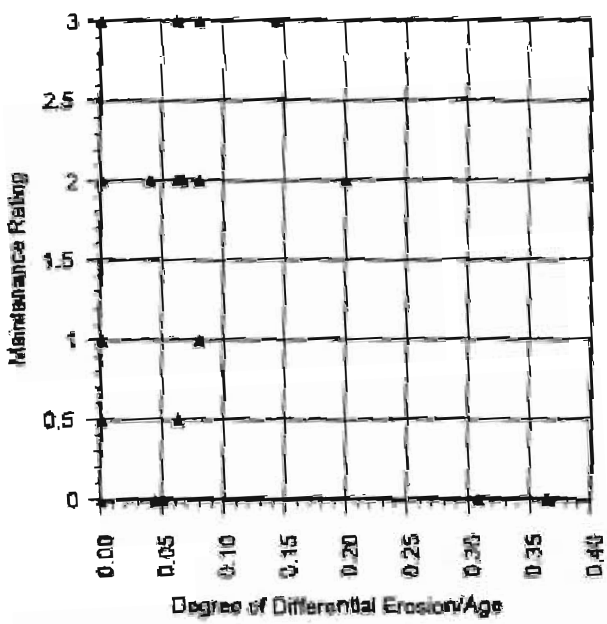


Fig. E.14 MR vs. DDE normalized by age of slope. Includes Glen Rose and Edwards over Glen Rose sites.

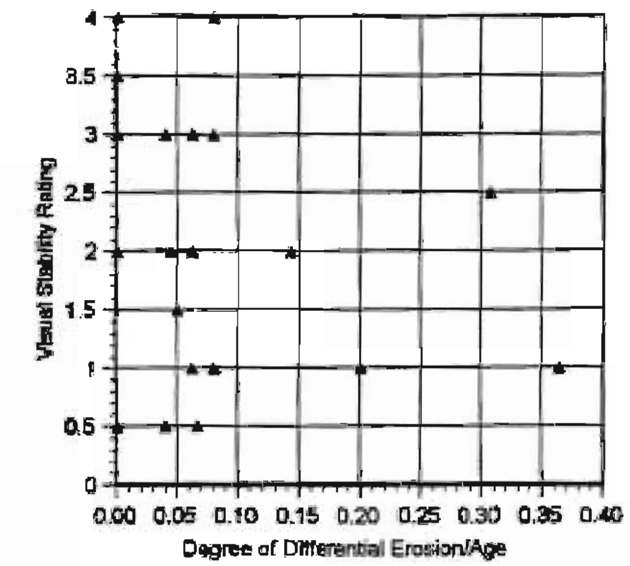


Fig. E.15 VSR vs. DDE normalized by age. Includes Glen Rose and Edwards over Glen Rose sites.

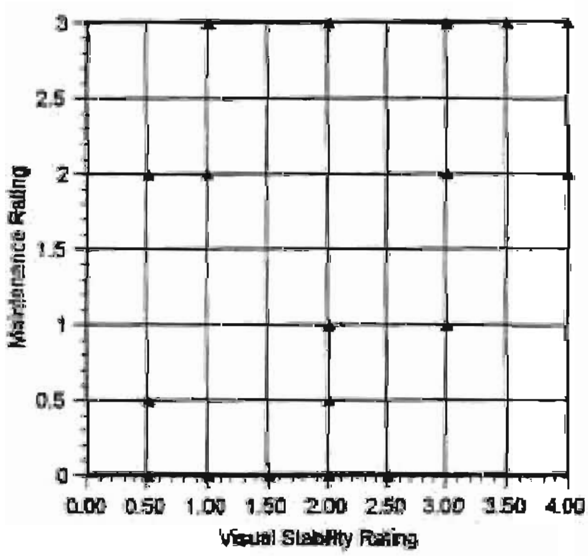


Fig. E.16 MR vs. VSR for Glen Rose sites. Notice there is no relationship between these two performance measures.

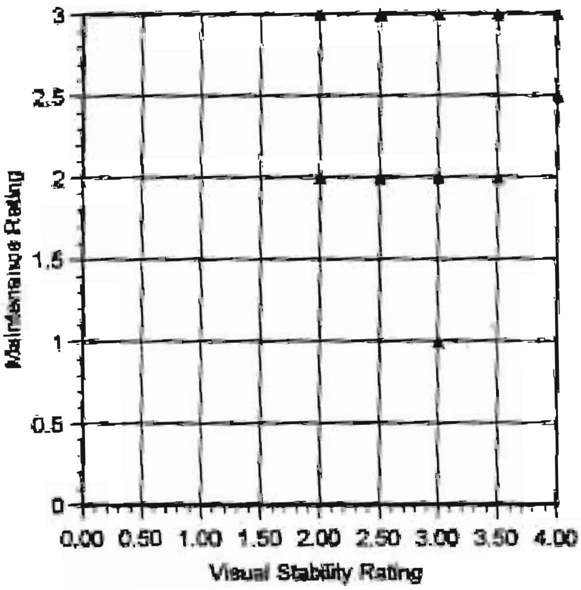


Fig. E.17 MR vs. VSR for Edwards sites. There is no correlation between the two, however, both variables are higher than those for the Glen Rose (see Fig. E.16).

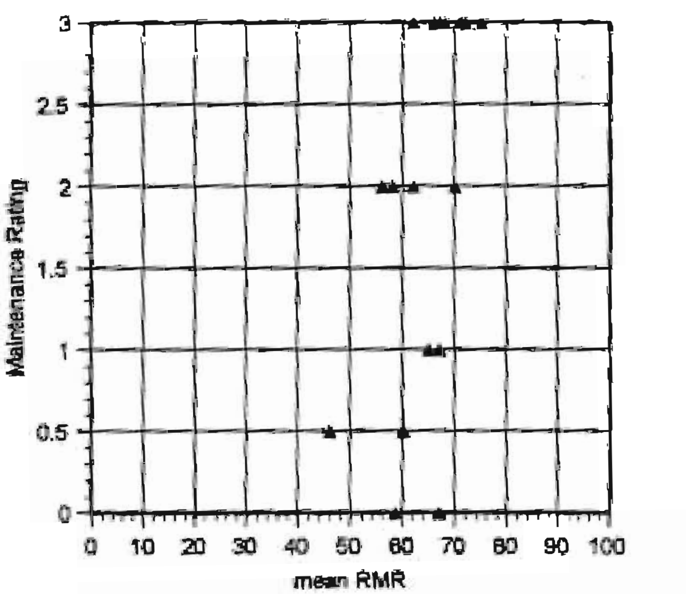


Fig. E.18 MR vs. average RMR for Glen Rose sites.

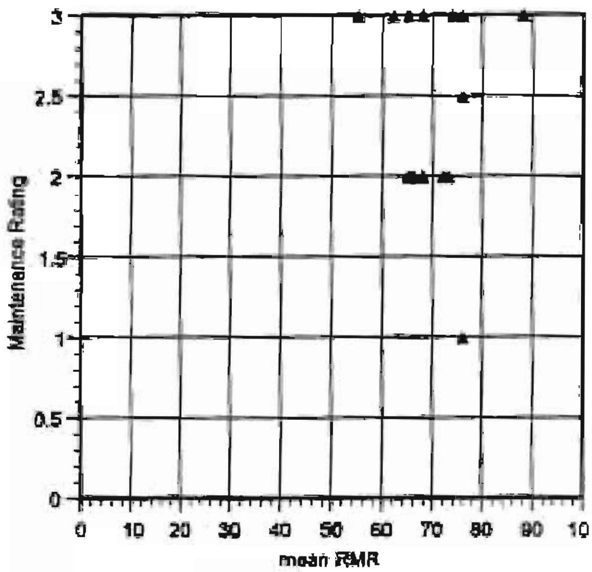


Fig. E.19 MR vs. average RMR for Edwards sites.

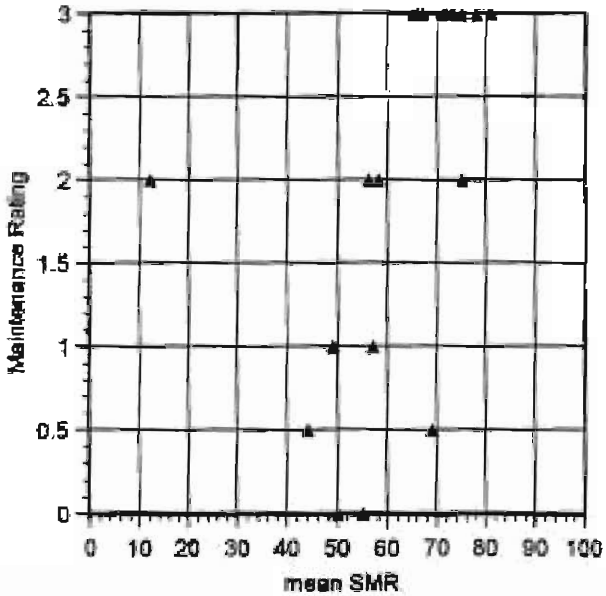


Fig. E.20 MR vs. average SMR for Glen Rose sites. Value at (12, 1.9) is site 2722-1 which has a joint set daylighting into the slope face, thus dramatically lowering the SMR.

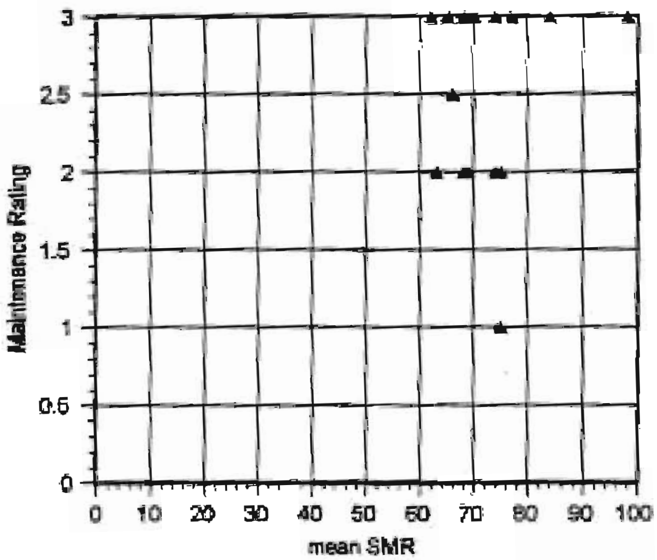


Fig. E.21 MR vs. average SMR for Edwards sites.

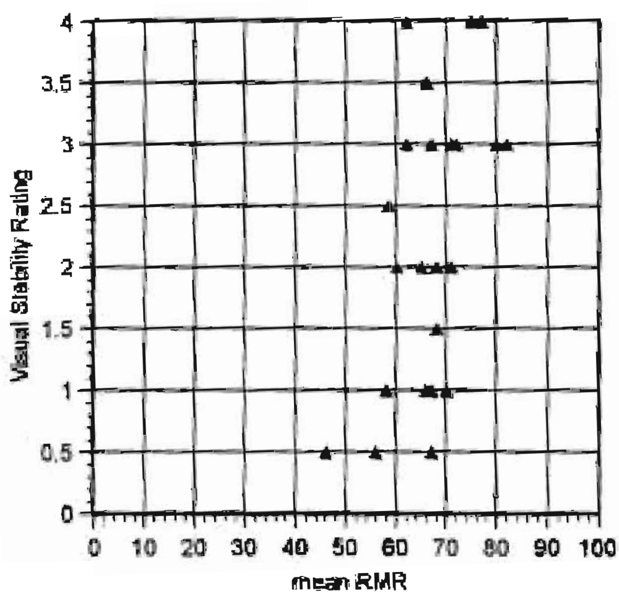


Fig. E.22 VSR vs. average RMR for Glen Rose sites.

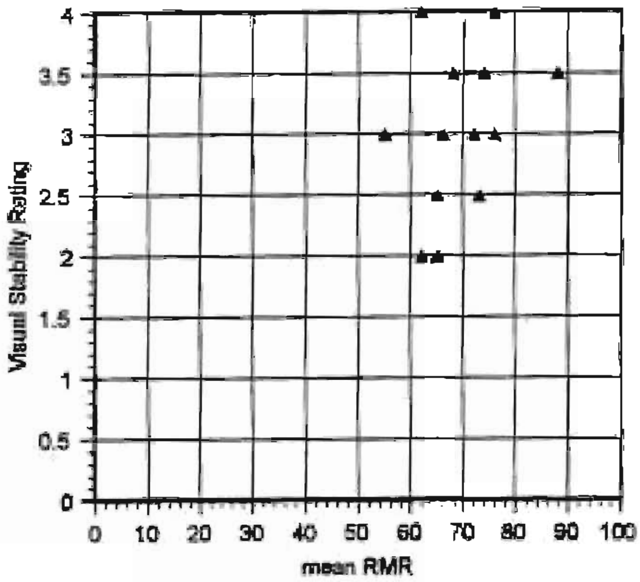


Fig. E.23 VSR vs. average RMR for Edwards sites.

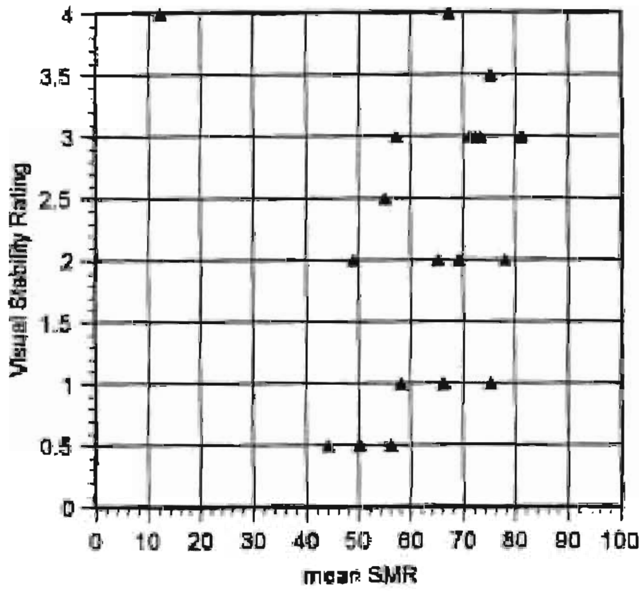


Fig. E.24 VSR vs. average SMR for Glen Rose sites.

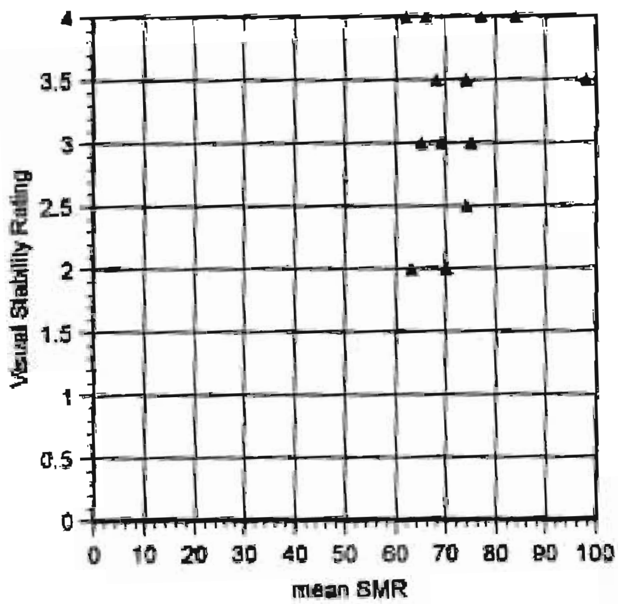


Fig. E.25 VSR vs. average SMR for Edwards sites.

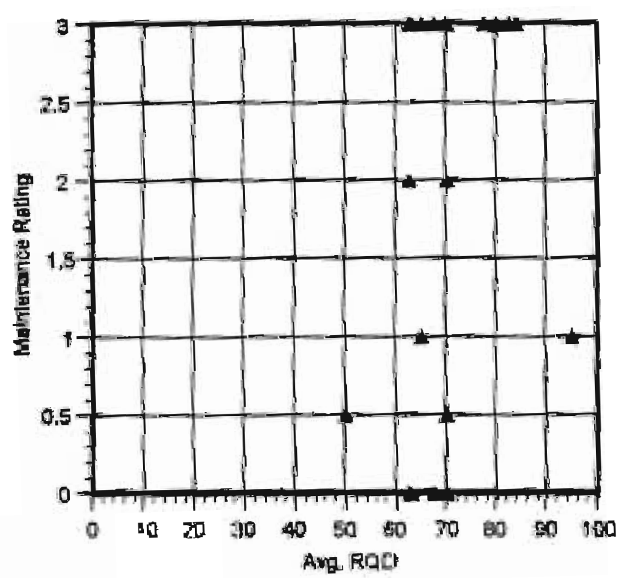


Fig. E.26 MR vs. average RQD for Glen Rose sites.

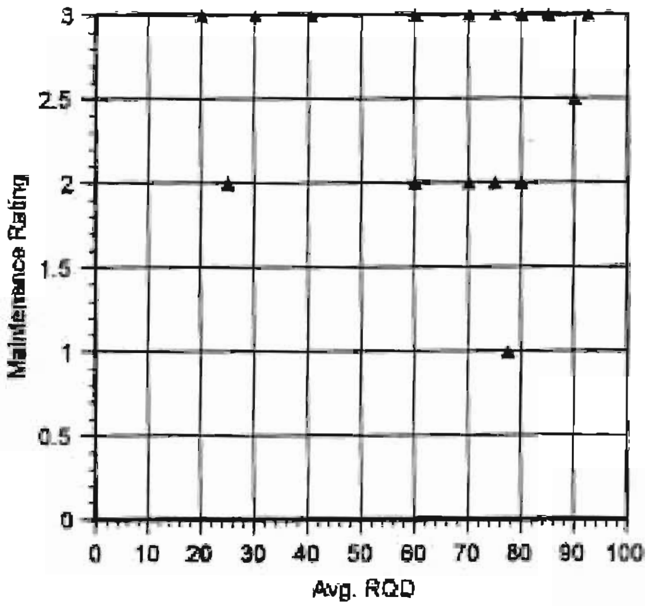


Fig. E.27 MR vs. average RQD for Edwards sites.

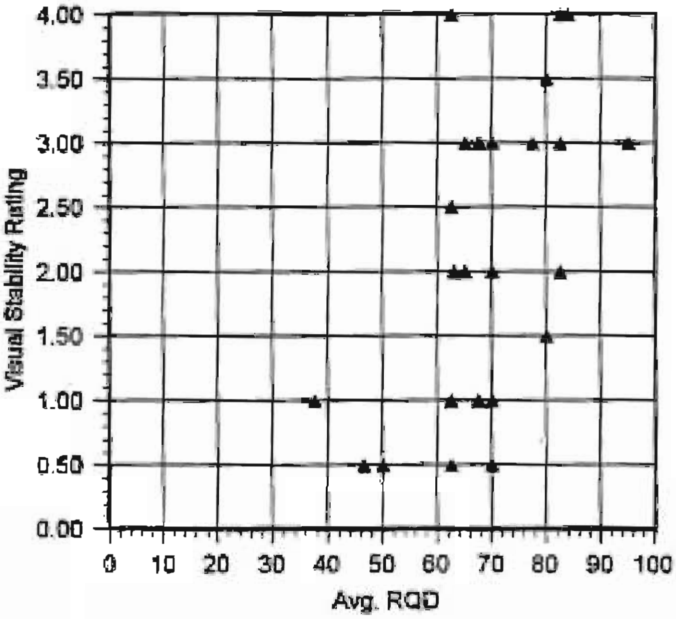


Fig. E.28 VSR vs. average RQD for Glen Rose sites. Notice slight relationship.

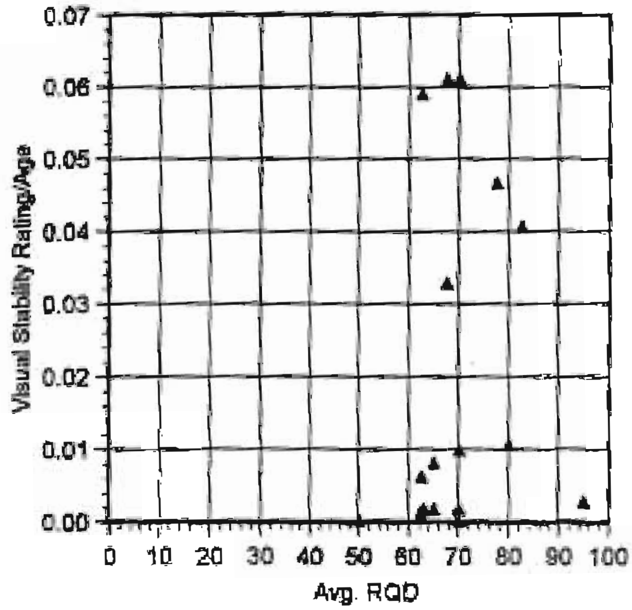


Fig. E.29 VSR normalized by slope age vs. average RQD for Glen Rose sites.

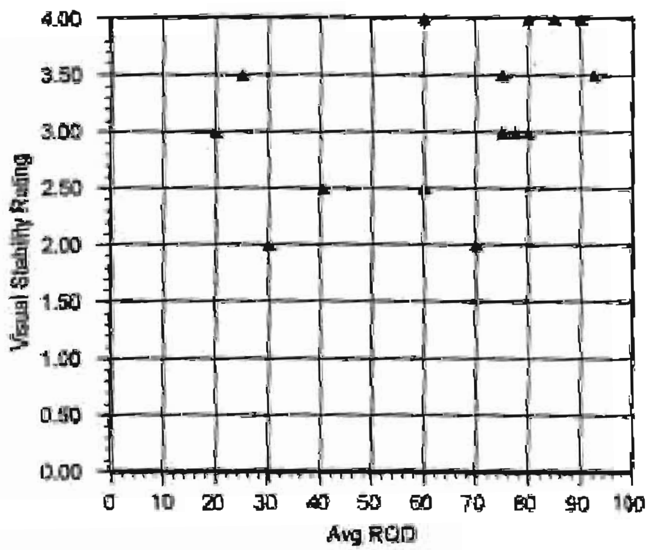


Fig. E.30 VSR vs. average RQD for Edwards sites.

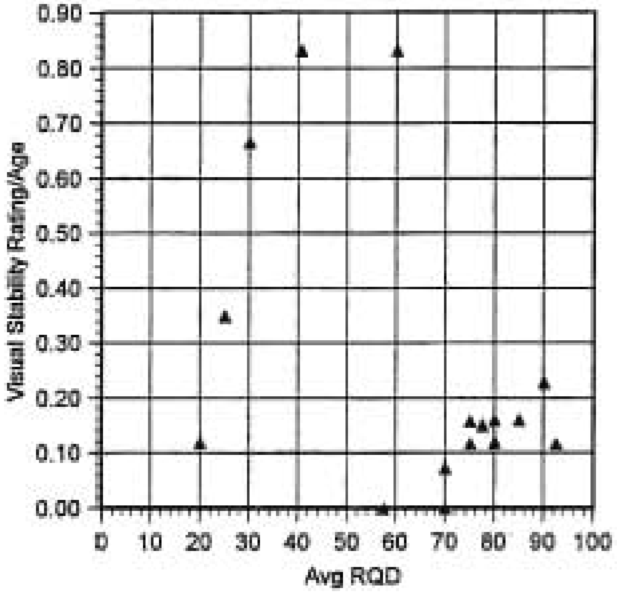


Fig. E.31 VSR normalized by slope age vs. average RQD for Edwards sites.

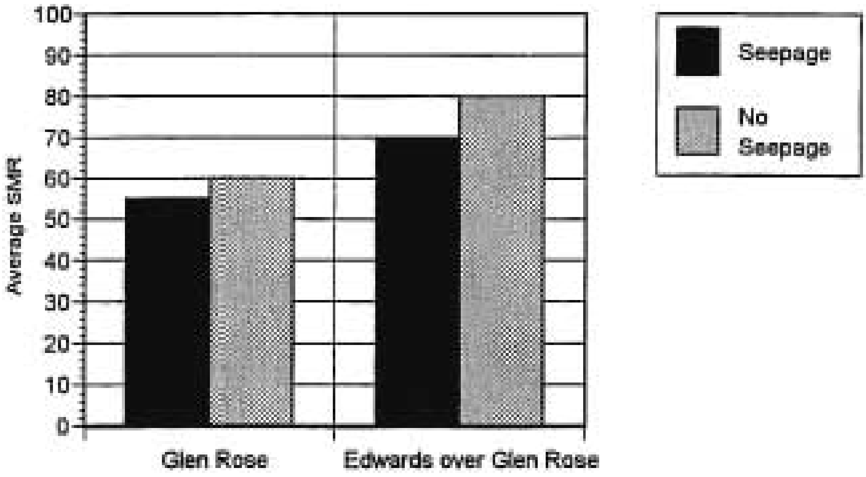


Fig. E.32 Effect of seepage on the average SMR ratings for Glen Rose and Edwards over Glen Rose sites.

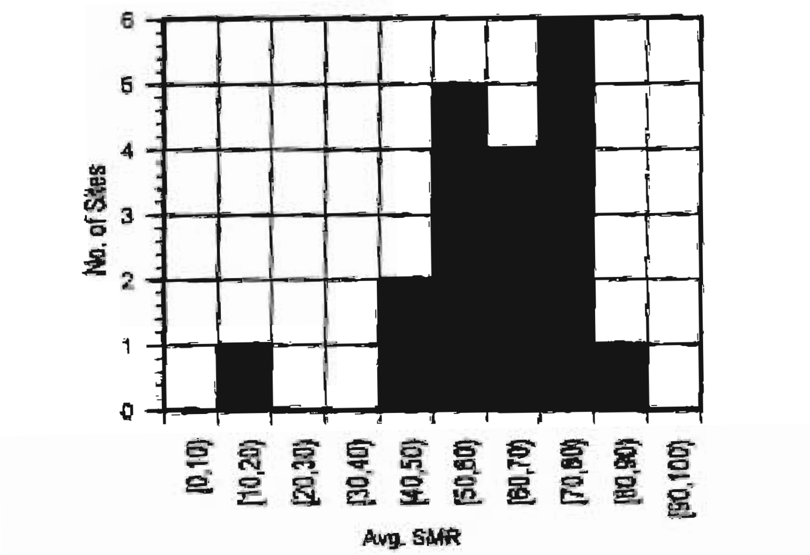


Fig. E.33 Distribution of average SMR values for Glen Rose sites.

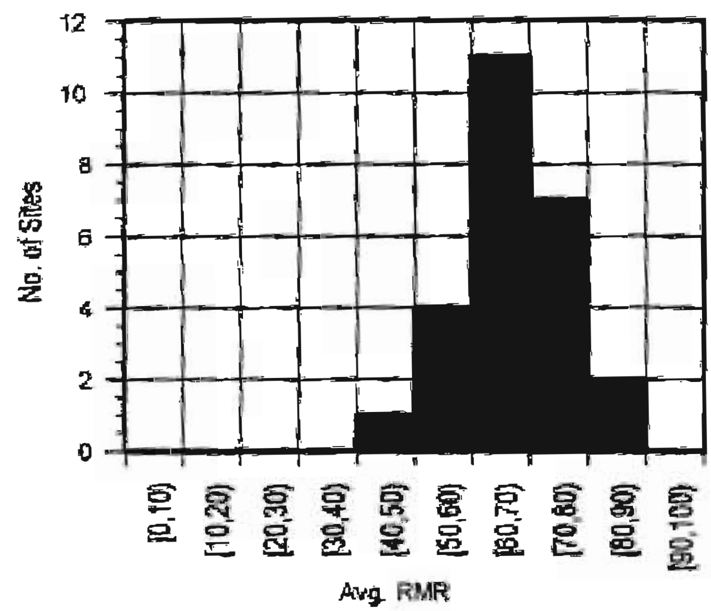


Fig. E.34 Distribution of average RMR values for Glen Rose sites.

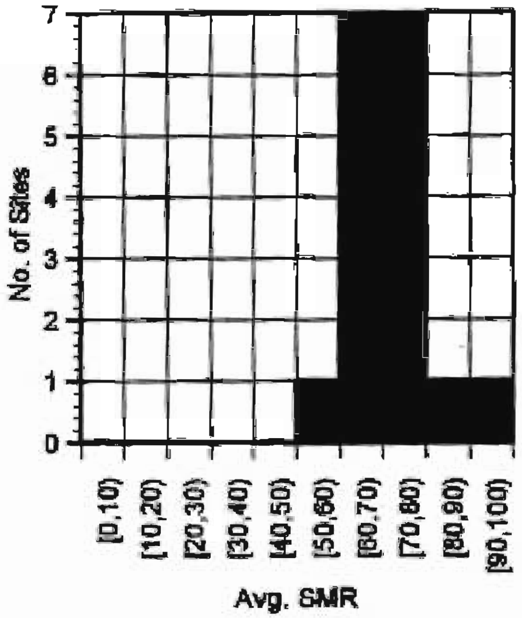


Fig. E.35 Distribution of SMR ratings for Edwards sites.

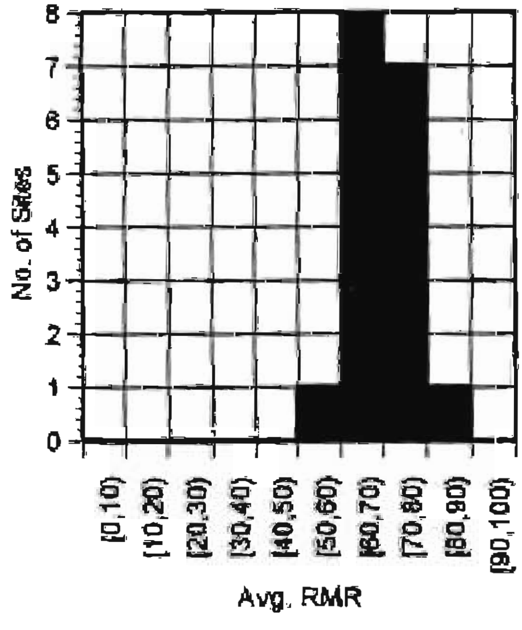


Fig. E.36 Distribution of RMR ratings for Edwards sites.

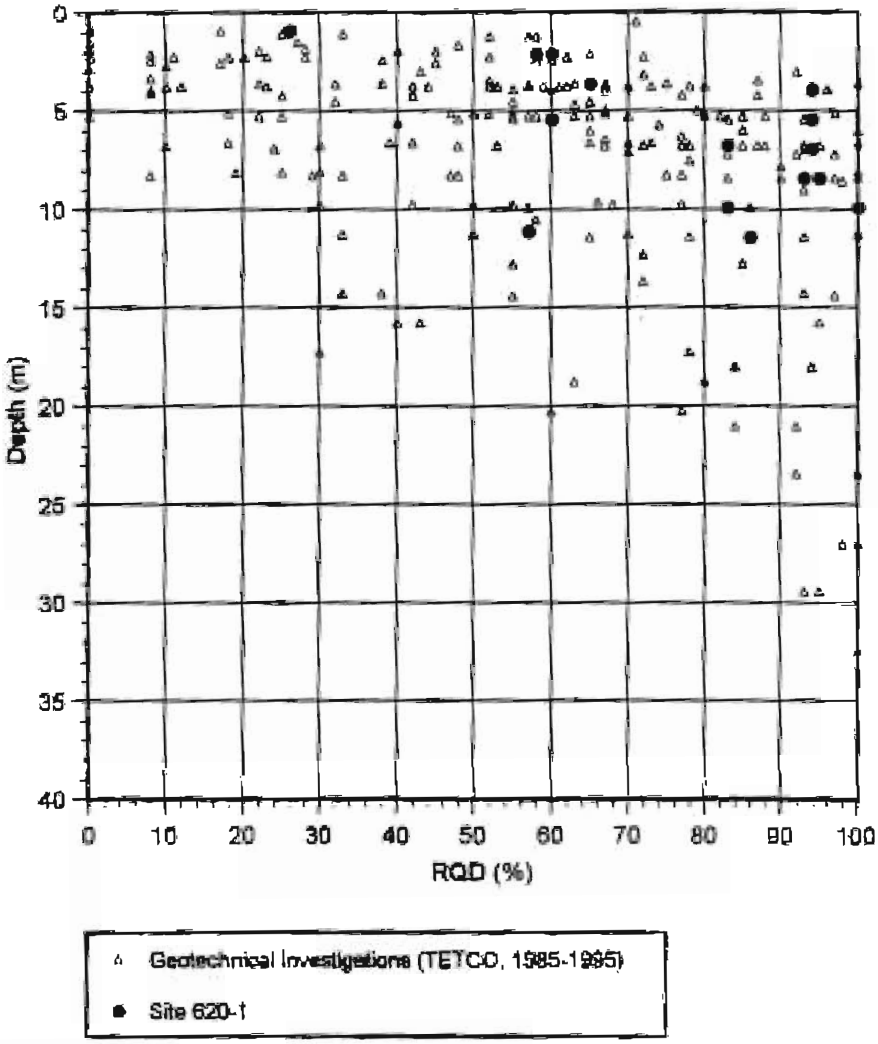


Fig. E.37 RQD vs. depth for Glen Rose Formation from CTR core borings and local geotechnical reports. Only 1.5 m or longer core runs were used for RQD determination. Notice the extreme variability at depths less than 10 m. This is most likely attributed to the weathered zone of the formation. Below 10 m, RQD shows a fair correlation with depth. The majority of road cuts observed for this project, in the Glen Rose, are 15 m or less in height.

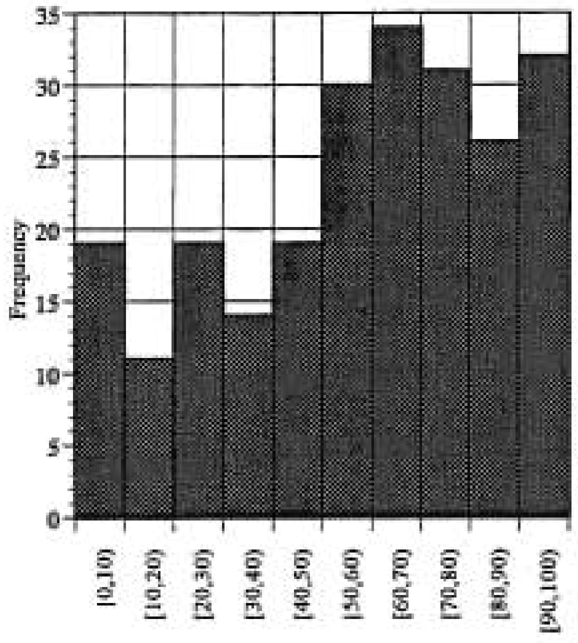


Fig. E.38 Distribution of RQD values for the Glen Rose in the Austin, TX area from local geotechnical reports (TETCO, 1985-1995).

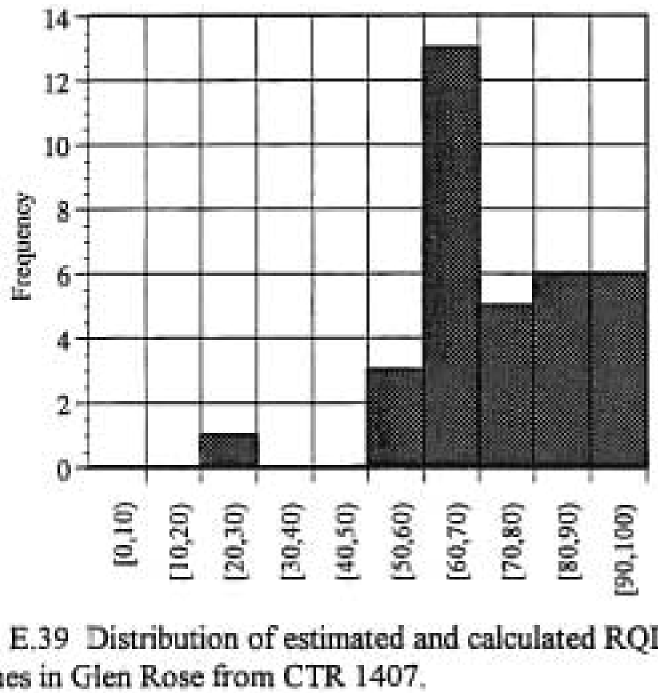


Fig. E.39 Distribution of estimated and calculated RQD values in Glen Rose from CTR 1407.

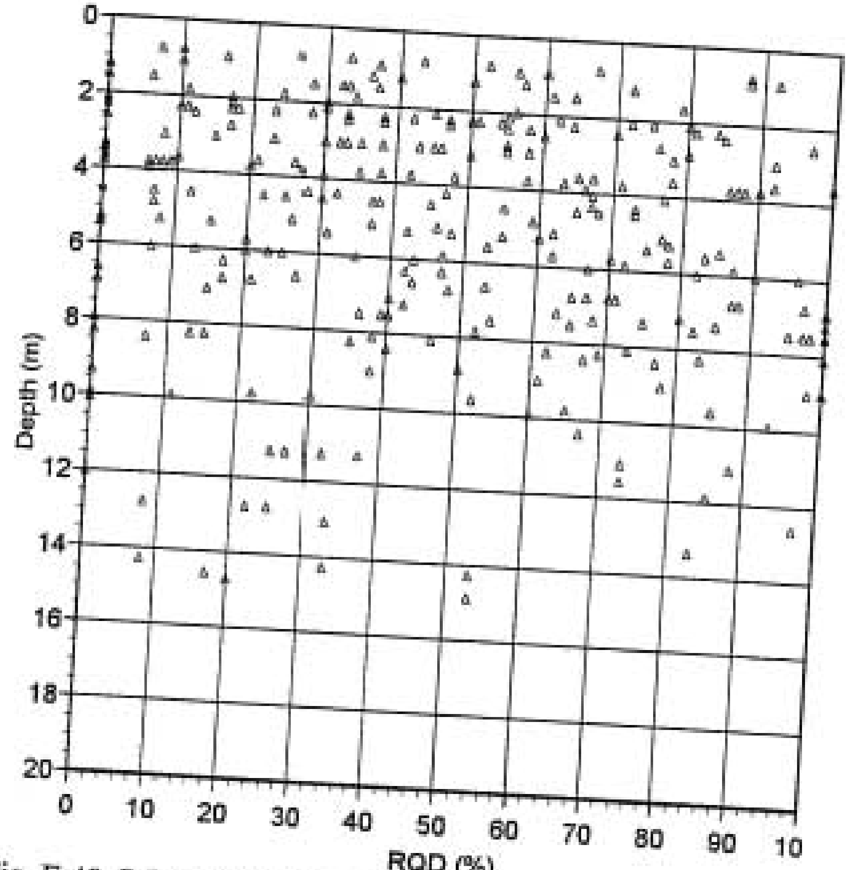


Fig. E.40 RQD vs. depth for Edwards Formation in Austin, TX area from geotechnical reports (TETCO, 1985-1995). Note the extreme variability , however, there are no data 15 m. Only 1.5 m or longer core runs were used for RQD determination.

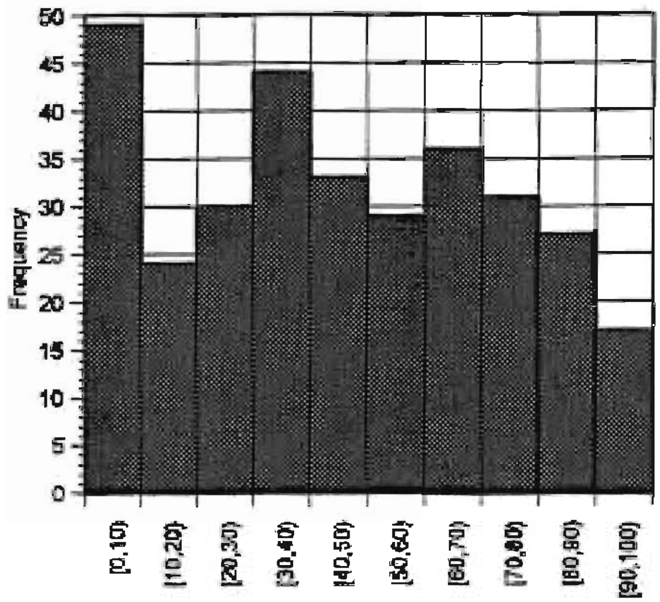


Fig. E.41 Distribution of RQD's from TETCO (1985-1995) for Edwards Formation in the Austin, TX area.

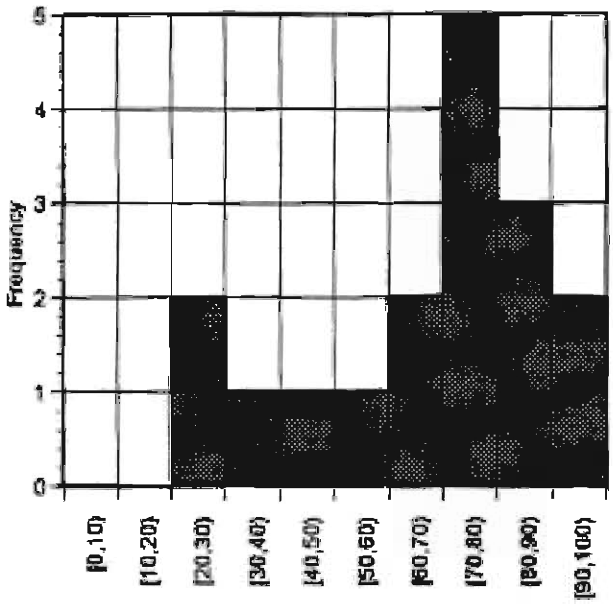


Fig. E.42 Calculated and estimated RQD's for Edwards sites for CTR 1407.

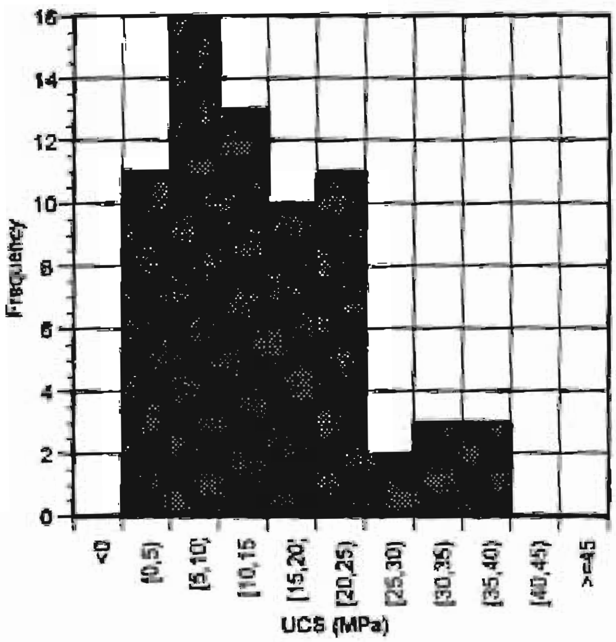


Fig. E.43 Distribution of uniaxial compressive strength values for Glen Rose Formation in the Austin, TX area from TETCO (1985-1995).

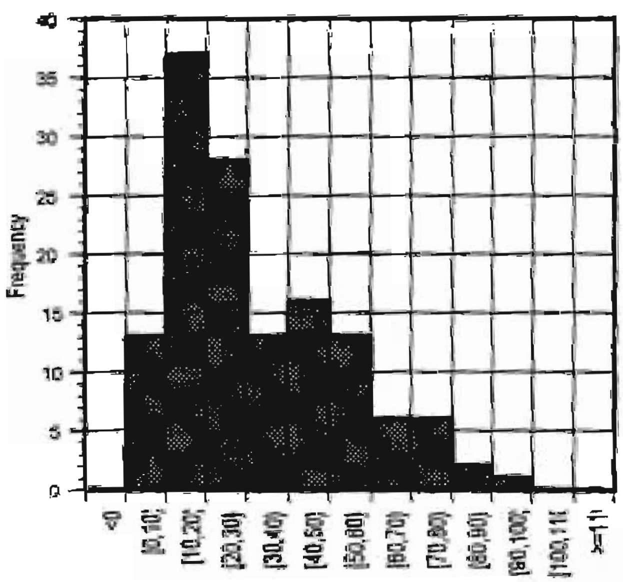


Fig. E.44 Distribution of UCS values for the Edwards Formation in the Austin, TX area from TETCO (1985-1995). Note that the UCS values for the Edwards are about 2 times greater than that of the Glen Rose (Fig. E.43).

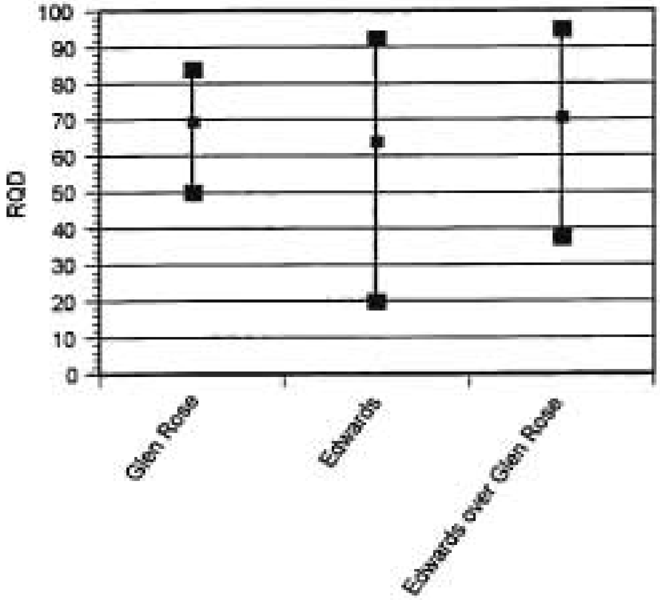


Fig. E.45 Average and range of estimated and/or calculated RQD's from sites in the Glen Rose and Edwards Formations.

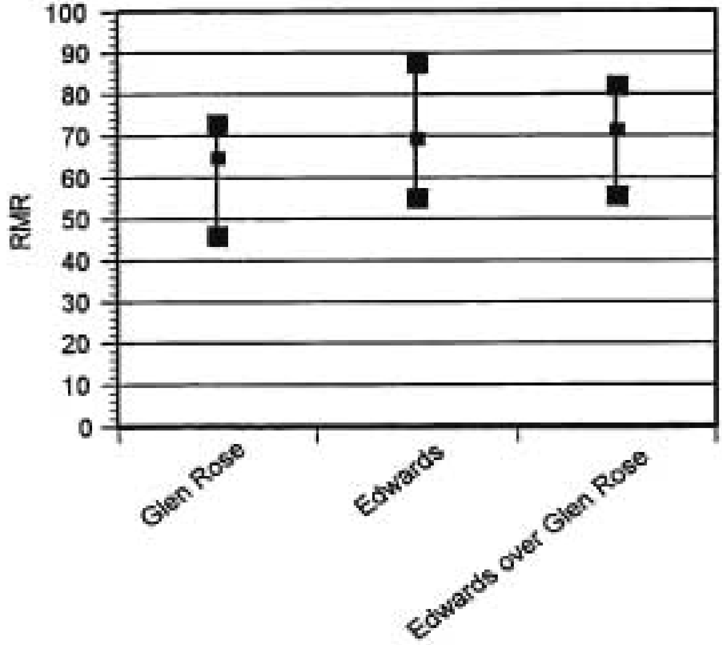


Fig. E.46 Average and range of RMR ratings for sites in the Edwards and Glen Rose Formations.

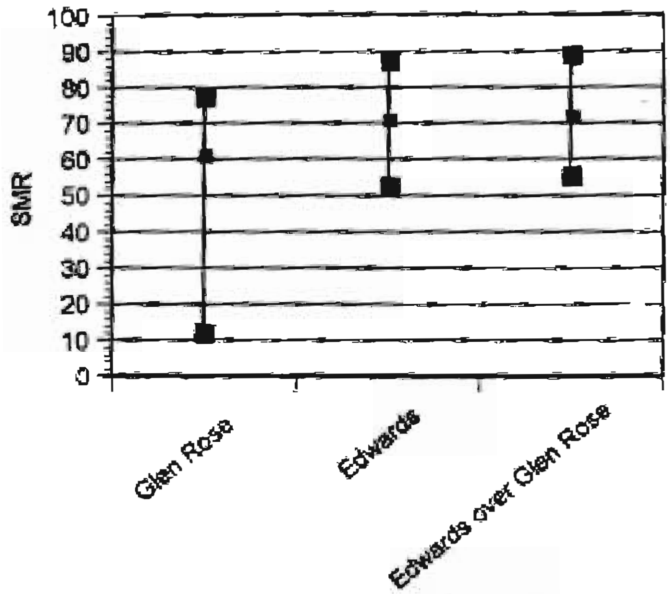


Fig. E.47 Average and range of SMR ratings for Edwards and Glen Rose Formations.

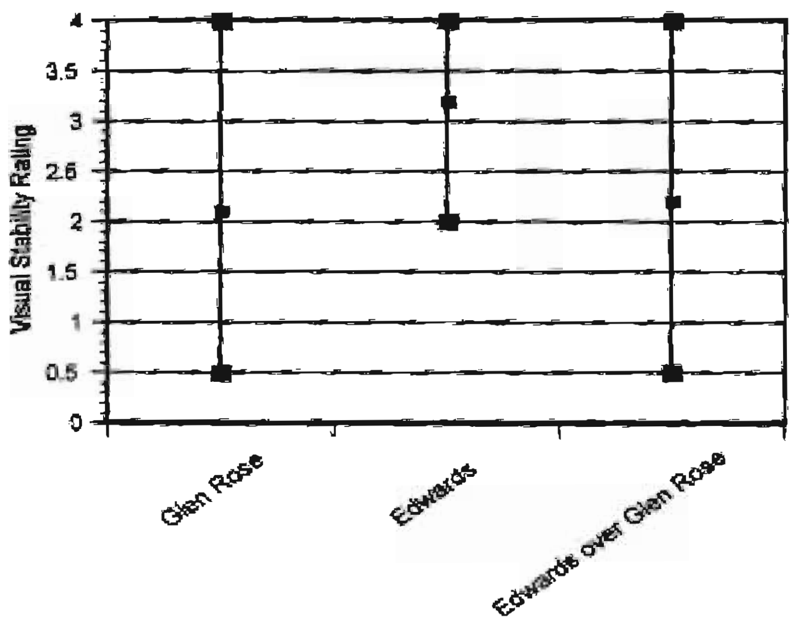


Fig. E.48 Average and range of VSR values. Notice the higher avg. VSR values for the Edwards Formation sites.

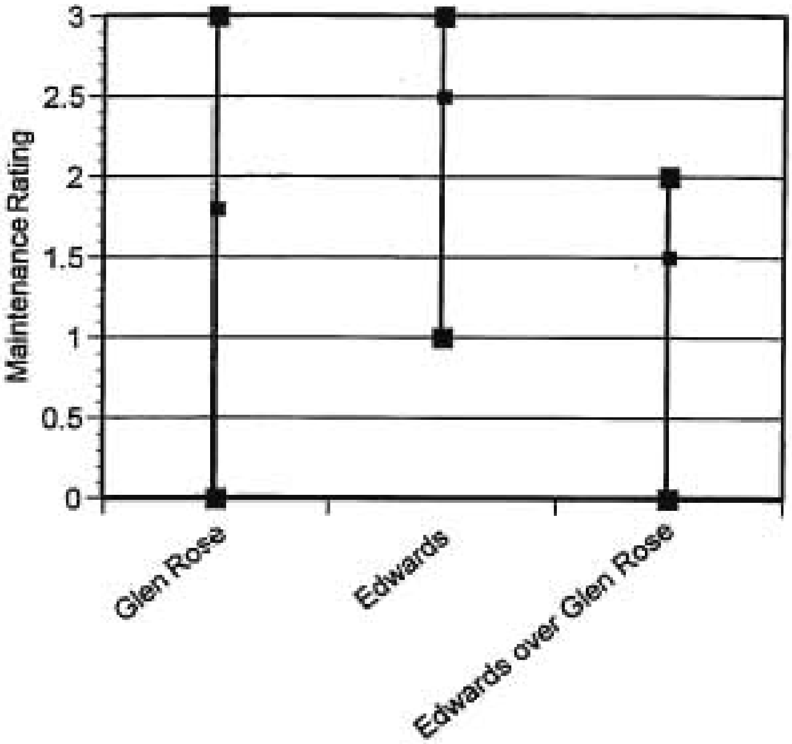


Fig. E.49 Average and range of MR values. Notice the higher average MR for the Edwards Formation.

TxDOT Rock Mass Field Description

Scanline Descriptions

Vertical Scanline Number: ________
Scanline Location (show on sketch): ________
Height of Scanline (ft): ________
Length of Scanline(ft): ________

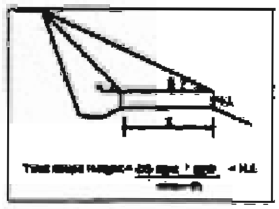


Photo Listing

No.	Description
6	
7	FAULT
8	BENCH
9	PAN LKG SE
10	SOIL N. OF FAULT
11	
12	J1
13	PAN LKG NW

Scanline Sketch

65T RQD

75-100

Samples Taken: None

Scanline Information:

obs #	Str.	Set	Strike w/r to exposure				Dip w/r to exposure				Persist.	Cond'n
			+/-20	20-45	45-90	RL	+/-20	20-45	45-90	RL		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

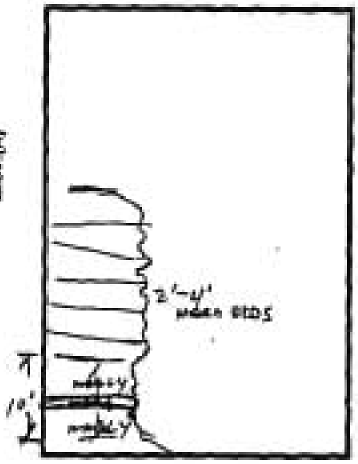
Date: 6/17
Page 1 of 4
Code 2673-1

TxDOT Rock Mass Field Description

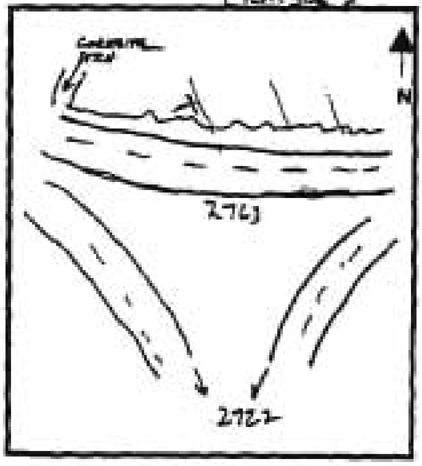
Formation: GLEN ROSE

Location: FM 2673 / FM 2722 INT.
COMAL CO.
(RM 50?)

TxDOT District: SAN ANTONIO



Profile Sketch



Plan Sketch

General Exposure Description

Dimensions and Orientation:

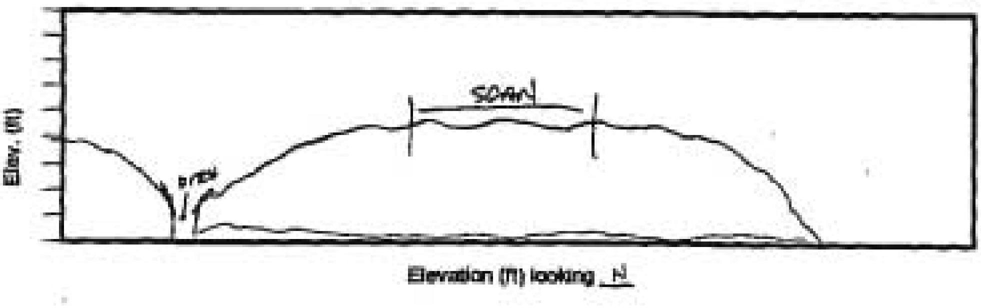
Total Height (ft): 25'
Lateral Extent (ft): 600'
~~Benches:~~ Height Width
L1
L2
L3

Face Orientation: Strike/dip: DUE W. TO N 80° W, VERT TO 20° LAYBACK
Catchment Description: SHALLOW DITCH; SET BACK 10'
Artificial Support: NONE

Method of Excavation (incl. effects): ?

Age of Exposure: ?

Vegetation Effects: SOME SMALL CEDARS GROWING OUT OF SLOPE



Elevation (ft) looking N

TxDOT Rock Mass Field Description

Summary of Engineering Geologic Data

Joint Description Summary

Set #	Strike	Dip	Roughness	Separation/ Filling	Persistence	Weathering	Remarks
1	N35°W	85°SW	VR	TIGHT AVG < 1/4"	P	II – III	FALL IN FILLING WHERE [illegible]

Other Structural Features

Feature	Strike	Dip	Condition	Persistence	Remarks

Occasional Random Joints? __________

Bedding Description: 2'-4' HARDER BEDS UPPER 15'; MARLY (2'-4') BEDS LOWER 10'. NOT AS SOFT AS MOST MARLY ~~[illegible]~~ MATL. OBSERVED IN OTHER SLOPES. JUST SOFTER THAN UPPER BEDS

Weathering/Erosion: DIFF. EROSION OF MARLY ZONE BUT ONLY 1'-2' RETREAT ONE SEEP IN LOWER MARL BED (DRIPPING)

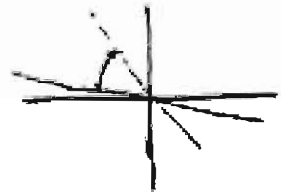
Form of Slope Failure/Degradation: CANTILEVER BLOCK FALL, BLOCK FALL, RAVELLING MOSTLY FROM LOWER 1/2 OF SLOPE

Debris: LOTS OF DEBRIS; SOIL TO 3' BLOCKS

Maintenance Record: __________

Available Geotechnical Data: __________

TxDOT Rock Mass Field Description



Scanline Descriptions

Horizontal Scanline Number: 1
Horizontal Location (locate on sketch): MID SLOPE
Height above base of cut (ft): 6'
If w/in one layer, layer thickness: ______
Length of scanline (ft): ONLY MEASURED APP. DISTANCE BTWN JOINTS, [illegible] MEAS. 5 TIMES
Strike of scanline (if different from face): ______

0+00 0+50 1+00

Scanline Sketch (include seepage locations)

Debris Description

Obs #	Siz.	Set	Strike w/r to exposure +/-20	Strike 20-45	Strike 45-90	Strike R/L	Dip w/r to exposure +/-20	Dip 20-45	Dip 45-90	Dip R/L	Persist.	Condition
1		1			X	R	X			L	P	TIGHT TO 4"/R/U/II-III/DRY
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												

Set	Apparent spacing (ft/scan length)	True Spacing (ft/scan length)
1	30-40"	25" AVE.
2		
3		
4		
5		

VARIES

TxDOT Rock Mass Field Description

Scanline Descriptions

Vertical Scanline Number: ________
Scanline Location (show on sketch): ________________________
Height of Scanline (ft): ________
Length of Scanline(ft): ________

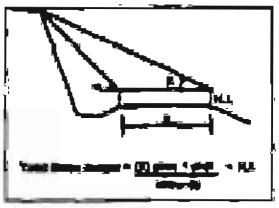


Photo Listing

No.	Description
14	FAN LKG W
15	[illegible]
16	VERT. PROFILE

Scanline Sketch

EST RQD
50-75

Samples Taken: NONE

Scanline Information:

obs #	Sta.	Set	Strike w/r to exposure				Dip w/r to exposure				Partial	Cond'n
			+/-30	30-45	45-60	N.L.	+/-30	30-45	45-60	N.L.		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

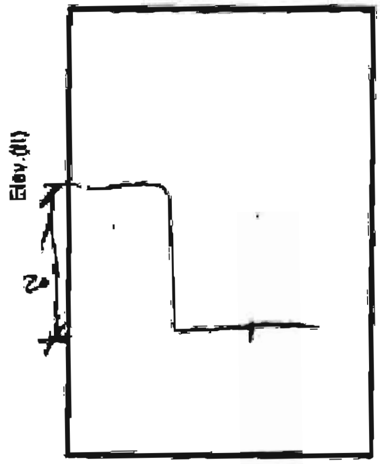
Date: 6/17
Page 1 of 1
Code 3159-1

TxDOT Rock Mass Field Description

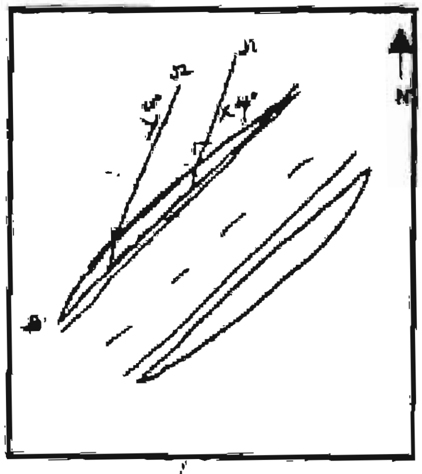
Formation: EDWARDS

Location: FM 3159 BTWN E.H. ½ MI [illegible] CANYON LAKE

TxDOT District: SAN ANTONIO



Profile Sketch LKG N



Plan Sketch

General Exposure Description

Dimensions and Orientation: HW CUT

Total Height (ft): [illegible]'

Lateral Extent (ft): 1200'

~~Benches:~~ Height Width

L1

L2

L3

Face Orientation: Strike/dip: N 45° E, 85° / 5° LAYBACK

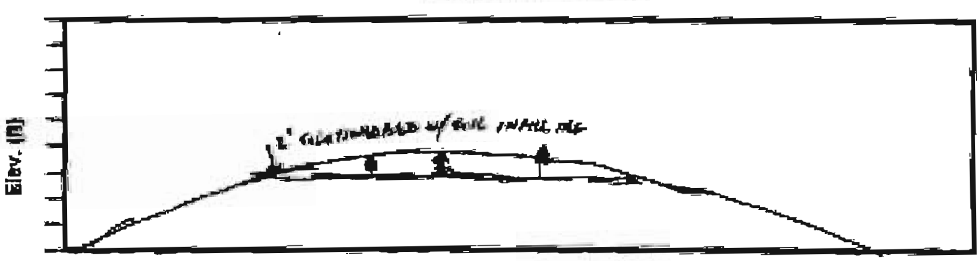
Catchment Description: ~~[illegible]~~ SET BACK

Artificial Support:

Method of Excavation (incl. effects): BLAST, SMOOTH WALL

Age of Exposure:

Vegetation Effects: OCC SHRUB GROWING OUT OF SOIL POCKETS



Elevation (ft) looking NW