PDHonline Course C250 (4 PDH)

Drilling and Sampling of Soil and Rock

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3.2.2 Non-Core (Destructive) Drilling

Non-core rock drilling is a relatively quick and inexpensive means of advancing a boring which can be considered when an intact rock sample is not required. Non-core drilling is typically used for determining the top of rock and is useful in solution cavity identification in karstic terrain. Types of non-core drilling include air-track drilling, down-the-hole percussive drilling, rotary tricone (roller bit) drilling, rotary drag bit drilling, and augering with carbide-tipped bits in very soft rocks. Drilling fluid may be water, mud, foam, or compressed air. Caution should be exercised when using these methods to define the top of soft rock since drilling proceeds rapidly, and cuts weathered and soft rock easily, frequently misrepresenting the top of rock for elevation or pile driving applications.

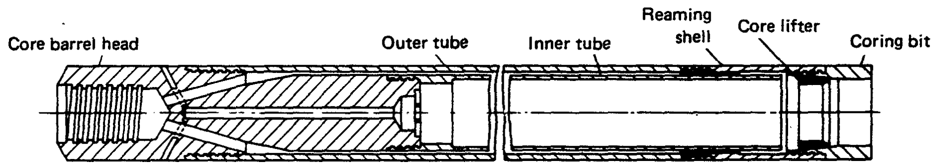
Because intact rock samples are not recovered in non-core drilling, it is particularly important for the field supervisor to carefully record observations during drilling. The following information pertaining to drilling characteristics should be recorded in the remarks section of the boring log:

- Penetration rate or drilling speed in minutes per 0.3 meter (1 ft)
- Dropping of rods
- Changes in drill operation by driller (down pressures, rotation speeds, etc.)
- Changes in drill bit condition
- Unusual drilling action (chatter, bouncing, binding, sudden drop)
- Loss of drilling fluid, color change of fluid, or change in drilling pressure

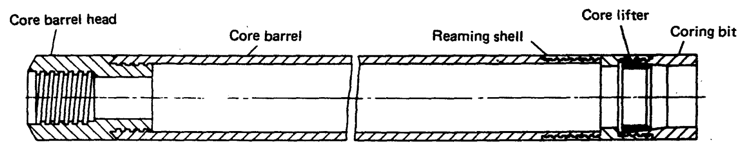
3.2.3 Types of Core Drilling

A detailed discussion of diamond core drilling is presented in AASHTO T 225 and ASTM D 2113. Types of core barrels may be single-tube, double-tube, or triple-tube, as shown in Figures 3-17a,b,c. Table 3-5 presents various types of core barrels available on the market. The standard is a double-tube core barrel, which offers better recovery by isolating the rock core from the drilling fluid stream and consists of an inner and outer core barrel as pictured in Figure 3-18. The inner tube can be rigid or fixed to the core barrel head and rotate around the core or it can be mounted on roller bearings which allow the inner tube to remain stationary while the outer tube rotates. The second or swivel type core barrel is less disturbing to the core as it enters the inner barrel and is useful in coring fractured and friable rock. In some regions only triple tube core barrels are used in rock coring. In a multi-tube system, the inner tube may be longitudinally split to allow observation and removal of the core with reduced disturbance.

Rock coring can be accomplished with either conventional or wireline equipment. With conventional drilling equipment, the entire string of rods and core barrel are brought to the surface after each core run to retrieve the rock core. Wireline drilling equipment allows the inner tube to be uncoupled from the outer tube and raised rapidly to the surface by means of a wire line hoist. The main advantage of wireline drilling over conventional drilling is the increased drilling production resulting from the rapid removal of the core from the hole which, in turn, decreases labor costs. It also provides improved quality of recovered core, particularly in soft rock, since this method avoids rough handling of the core barrel during retrieval of the barrel from the borehole and when the core barrel is opened. (Drillers often hammer on the core barrel to break it from the drill rods and to open the core barrel, causing the core to break.) Wireline drilling can be used on any rock coring job, but typically, it is used on projects where bore holes are greater than 25 m deep and rapid removal of the core from the hole has a greater effect on cost. Wireline drilling is also an effective method for both rock and soil exploration though cobbles or boulders, which tend to shift and block off the bore hole.



(a)



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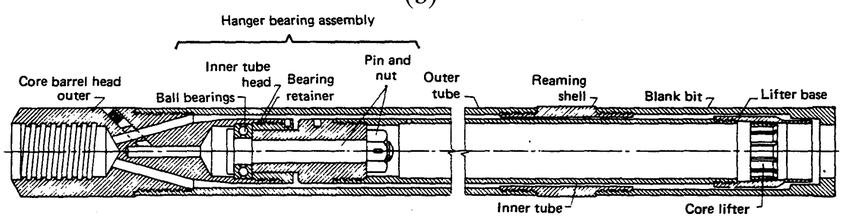


(c)

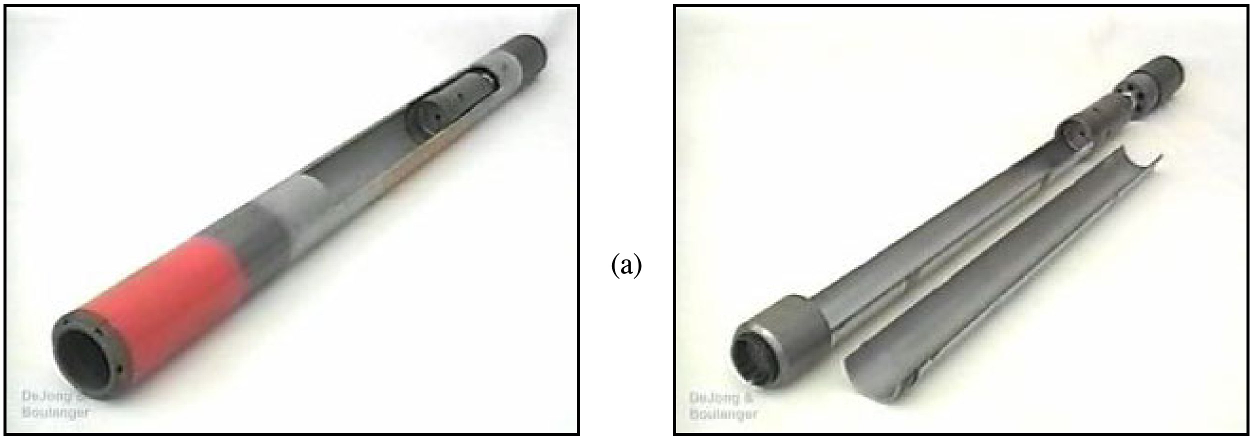
Figure 3-17. (a) Single Tube Core Barrel; (b) Rigid Type Double Tube Core Barrel; (c) Swivel Type Double Tube Core Barrel, Series "M" with Ball Bearings (Courtesy of Sprague & Henwood, Inc.).

TABLE 3-5.

DIMENSIONS OF CORE SIZES

(after Christensen Dia-Min Tools, Inc.)

Size	Diameter of Core mm (in)	Diameter of Borehole mm (in)
EX,EXM	21.5 (0.846)	37.7 (1.484)
EWD3	21.2 (0.835)	37.7 (1.484)
AX	30.1 (1.185)	48.0 (1.890)
AWD4, AWD3	28.9 (1.138)	48.0 (1.890)
AWM	30.1 (1.185)	48.0 (1.890)
AQ Wireline, AV	27.1 (1.067)	48.0 (1.890)
BX	42.0 (1.654)	59.9 (2.358)
BWD4, BWD3	41.0 (1.614)	59.9 (2.358)
BXB Wireline, BWC3	36.4 (1.433)	59.9 (2.358)
BQ Wireline, BV	36.4 (1.433)	59.9 (2.358)
NX	54.7 (2.154)	75.7 (2.980)
NWD4,NWD3	52.3 (2.059)	75.7 (2.980)
NXB Wireline, NWC3	47.6 (1.874)	75.7 (2.980)
NQ Wireline, NV	47.6 (1.874)	75.7 (2.980)
HWD4,HXB Wireline, HWD3	61.1 (2.406)	92.7 (3.650)
HQ Wireline	63.5 (2.500)	96.3 (3.791)
CP, PQ Wireline	85.0 (3.346)	122.6 (4.827)



(a)

(a) (b)

Figure 3-18. Double Tube Core Barrel. (a) Outer barrel assembly (b) Inner barrel assembly.

Although NX is the size most frequently used for engineering explorations, larger and smaller sizes are in use. Generally, a larger core size will produce greater recovery and less mechanical breakage. Because of their effect on core recovery, the size and type of coring equipment used should be carefully recorded in the appropriate places on the boring log.

The length of each core run should be limited to 3 m maximum. Core run lengths should be reduced to 1.5 m (5 ft), or less, just below the rock surface and in highly fractured or weathered rock zones. Shorter core runs often reduce the degree of damage to the core and improve core recovery in poor quality rock.

Figure 3-19. Coring Bits. From left to right: Diamond, Carbide, & Sawtooth.

Coring Bits

The coring bit is the bottommost component of the core barrel assembly. It is the grinding action of this component that cuts the core from the rock mass. Three basic categories of bits are in use: diamond, carbide insert, and sawtooth (Figure 3-19). Coring bits are generally selected by the driller and are often approved by the geotechnical engineer. Bit selection should be based on general knowledge of drill bit performance for the expected formations and the proposed drilling fluid.

Diamond coring bits which may be of surface set or impregnated-diamond type are the most versatile since they can produce high-quality cores in rock materials ranging from soft to extremely hard. Compared to other types, diamond bits in general permit more rapid coring and as noted by Hvorslev (1949), exert lower torsional stresses on the core. Lower torsional stresses permit the retrieval of longer cores and cores of small diameter. The wide variation in the hardness, abrasiveness, and degree of fracturing encountered in rock has led to the design of bits to meet specific conditions known to exist or encountered at given sites. Thus, wide variations in the quality, size, and spacing of diamonds, in the composition of the metal matrix, in the face contour, and in the type and number of waterways are found in bits of this type. Similarly, the diamond content and the composition of the metal matrix of impregnated bits are varied to meet differing rock conditions.

Carbide bits use tungsten carbide in lieu of diamonds and are of several types (the standard type is shown in Figure 3-19). Bits of this type are used to core soft to medium-hard rock. They are less expensive than diamond bits. However, the rate of drilling is slower than with diamond bits.

Sawtooth bits consist of teeth cut into the bottom of the bit. The teeth are faced and tipped with a hard metal alloy such as tungsten carbide to provide water resistance and thereby to increase the life of the bit. Although these bits are less expensive than diamond bits, they do not provide as high a rate of coring and do not have a salvage value. The saw tooth bit is used primarily to core overburden and very soft rock.

An important feature of all bits which should be noted is the type of waterways provided in the bits for passage of drilling fluid. Bits are available with so-called "conventional" waterways, which are passages cut on the interior face of the bit), or with bottom discharge waterways, which are internal and discharge at the bottom face of the bit behind a metal skirt separating the core from the discharge fluid. Bottom discharge bits should be used when coring soft rock or rock having soil-filled joints to prevent erosion of the core by the drilling fluid before the core enters the core barrel.

Drilling Fluid

In many instances, clear water is used as the drilling fluid in rock coring. If drilling mud is required to stabilize collapsing holes or to seal zones when there is loss of drill water, the design engineer, the geologist and the geotechnical engineer should be notified to confirm that the type of drilling mud is acceptable. Drilling mud will clog open joints and fractures, which adversely affects permeability measurements and piezometer installations. Drilling fluid should be contained in a settling basin to remove drill cuttings and to allow recirculation of the fluid. Generally, drilling fluids can be discharged onto the ground surface. However, special precautions or handling may be required if the material is contaminated with oil or other substances and may require disposal off site. Water flow over the ground surface should be avoided, as much as possible.

3.2.4 Observation During Core Drilling

Drilling Rate/Time

The drilling rate should be monitored and recorded on the boring log in the units of minutes per 0.3 m (1 ft). Only time spent advancing the boring should be used to determine the drilling rate.

Core Photographs

Cores in the split core barrel should be photographed immediately upon removal from the borehole. A label should be included in the photograph to identify the borehole, the depth interval and the number of the core runs. It may be desirable to get a "close-up" of interesting features in the core. Wetting the surface of the recovered core using a spray bottle and/or sponge prior to photographing will often enhance the color contrasts of the core.

A tape measure or ruler should be placed across the top or bottom edge of the box to provide a scale in the photograph. The tape or ruler should be at least 1 meter (3 ft) long, and it should have relatively large, high contrast markings to be visible in the photograph.

A color bar chart is often desirable in the photograph to provide indications of the effects of variation in film age, film processing, and the ambient light source. The photographer should strive to maintain uniform light conditions from day to day, and those lighting conditions should be compatible with the type of film selected for the project.

Rock Classification

The rock type and its inherent discontinuities, joints, seams, and other facets should be documented. See Section 4.7 for a discussion of rock classification and other information to be recorded for rock core.

Recovery

The core recovery is the length of rock core recovered from a core run, and the recovery ratio is the ratio of the length of core recovered to the total length of the core drilled on a given run, expressed as either a fraction or a percentage. Core length should be measured along the core centerline. When the recovery is less than the length of the core run, the non-recovered section should be assumed to be at the end of the run unless there is reason to suspect otherwise (e.g., weathered zone, drop of rods, plugging during drilling, loss of fluid, and rolled or recut pieces of core). Non-recovery should be marked as NCR (no core recovery) on the boring log, and entries should not be made for bedding, fracturing, or weathering in that interval.

Recoveries greater than 100 percent may occur if core that was not recovered during a run is subsequently recovered in a later run. These should be recorded and adjustments to data should not be made in the field.

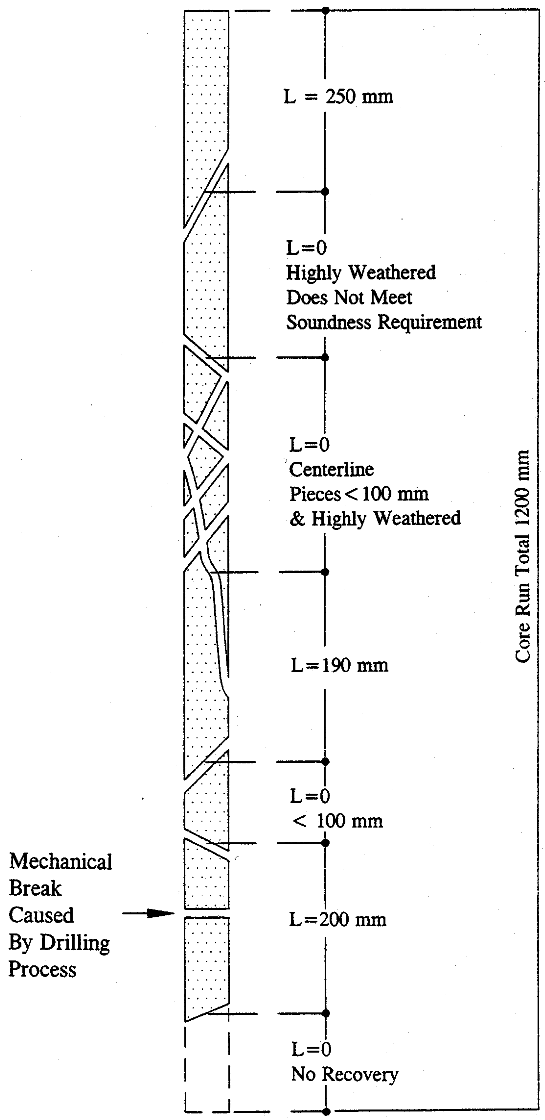
Rock Quality Designation (RQD)

The RQD is a modified core recovery percentage in which the lengths of all pieces of sound core over 100 mm (4 in) long are summed and divided by the length of the core run. The correct procedure for measuring RQD is illustrated in Figure 3-20. The RQD is an index of rock quality in that problematic rock that is highly weathered, soft, fractured, sheared, and jointed typically yields lower RQD values. Thus, RQD is simply a measurement of the percentage of "good" rock recovered from an interval of a borehole. It should be noted that the original correlation for RQD (Rock Quality Designation) reported by Deere (1963) was based on measurements made on NX-size core. Experience in recent years reported by Deere and Deere (1989) indicates that cores with diameters both slightly larger and smaller than NX may be used for computing RQD. The wire line cores using NQ, HQ, and PQ are also considered acceptable. The smaller BQ and BX sizes are discouraged because of a higher potential for core breakage and loss.

<u>Length Measurements of Core Pieces</u>

The same piece of core could be measured three ways: along the centerline, from tip to tip, or along the fully circular barrel section (Figure 3-21). The recommended procedure is to measure the core length along the centerline. This method is advocated by the International Society for Rock Mechanics (ISRM), Commission on Standardization of Laboratory and Field Tests (1978, 1981). The centerline measurement is preferred because: (1) it results in a standardized RQD not dependent on the core diameter, and (2) it avoids unduly penalizing of the rock quality for cases where the fractures parallel the borehole and are cut by a second set.

Core breaks caused by the drilling process should be fitted together and counted as one piece. Drilling breaks are usually evidenced by rough fresh surfaces. For schistose and laminated rocks, it is often difficult to discern the difference between natural breaks and drilling breaks. When in doubt about a break, it should be considered as natural in order to be conservative in the calculation of RQD for most uses. It is noted that this practice would not be conservative when the RQD is used as part of a ripping or dredging estimate.



$$RQD = \frac{\sum \text{Length of Sound Core Pieces} > 100\,mm}{\text{Total Core Run Length}}$$

$$RQD = \frac{250 + 190 + 200}{1200} \times 100\%$$

RQD = 53% (Fair)

Rock Quality Description

RQD (Rock Quality Designation)	Description of Rock Quality
0 - 25%	Very Poor
25 - 50%	Poor
50 - 75%	Fair
75 - 90%	Good
90 - 100%	Excellent

Figure 3-20. Modified Core Recovery as an Index of Rock Mass Quality.

Assessment of Soundness

Pieces of core which are not "hard and sound" should not be counted for the RQD even though they possess the requisite 100 mm (3.94 in) length. The purpose of the soundness requirement is to downgrade the rock quality where the rock has been altered and weakened either by agents of surface weathering or by hydrothermal activity. Obviously, in many instances, a judgment decision must be made as to whether or not the degree of chemical alteration is sufficient to reject the core piece.

One commonly used procedure is not to count a piece of core if there is any doubt about its meeting the soundness requirement (because of discolored or bleached grains, heavy staining, pitting, or weak grain boundaries). This procedure may unduly penalize the rock quality, but it errs on the side of conservatism. A second procedure which occasionally has been used is to include the altered rock within the RQD summed percentage, but to indicate by means of an asterisk (RQD*) that the soundness requirements have not been met. The advantage of the method is that the RQD* will provide some indication of the rock quality with respect to the degree of fracturing, while also noting its lack of soundness.

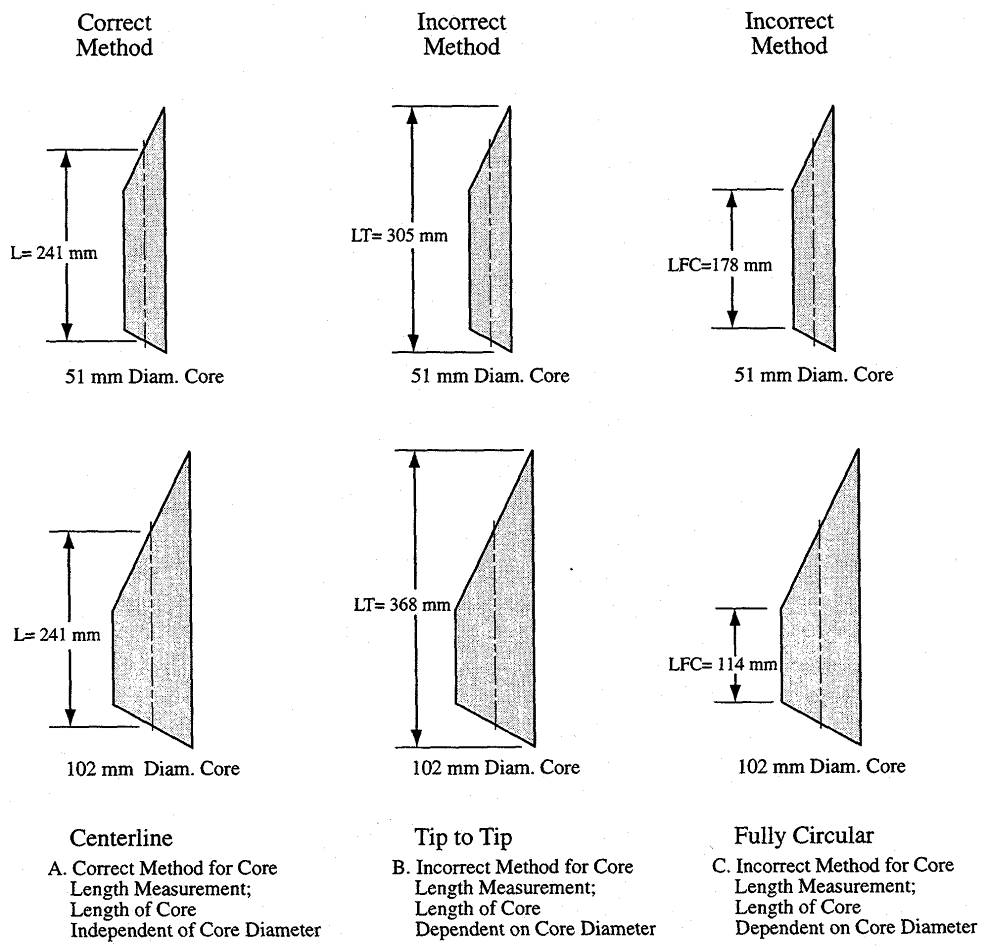


Figure 3-21. Length Measurement of Core RQD Determination.

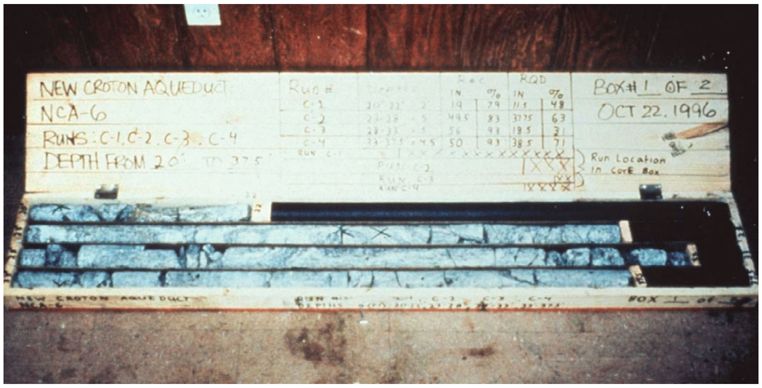
Drilling Fluid Recovery

The loss of drilling fluid during the advancement of a boring can be indicative of the presence of open joints, fracture zones or voids in the rock mass being drilled. Therefore, the volumes of fluid losses and the intervals over which they occur should be recorded. For example, "no fluid loss" means that no fluid was lost except through spillage and filling the hole. "Partial fluid loss" means that a return was achieved, but the amount of return was significantly less than the amount being pumped in. "Complete water loss" means that no fluid returned to the surface during the pumping operation. A combination of opinions from the field personnel and the driller on this matter will result in the best estimate.

Core Handling and Labeling

Rock cores from geotechnical explorations should be stored in structurally sound core boxes made of wood or corrugated waxed cardboard (Figure 3-22). Wooden boxes should be provided with hinged lids, with the hinges on the upper side of the box and a latch to secure the lid in a closed position.

Cores should be handled carefully during transfer from barrel to box to preserve mating across fractures and fracture-filling materials. Breaks in core that occur during or after the core is transferred to the core box



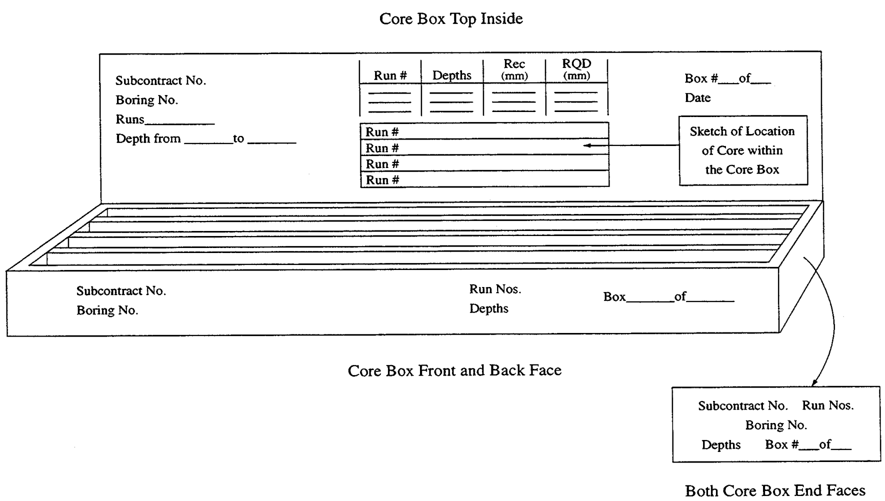


Figure 3-22. Core Box for Storage of Recovered Rock and Labeling.

should be refitted and marked with three short parallel lines across the fracture trace to indicate a mechanical break. Breaks made to fit the core into the core box and breaks made to examine an inner core surface should be marked as such. These deliberate breaks should be avoided unless absolutely necessary. Cores should be placed in the boxes from left to right, top to bottom. When the upper compartment of the box is filled, the next lower (or adjoining) compartment (and so on until the box is filled) should be filled, beginning in each case at the left-hand side. The depths of the top and bottom of the core and each noticeable gap in the formation should be marked by a clearly labeled wooden spacer block.

If there is less than 100 percent core recovery for a run, a cardboard tube spacer of the same length as the core loss should be placed in the core box either at the depth of core loss, if known, or at the bottom of the run. The depth of core loss, if known, or length of core loss should be marked on the spacer with a black permanent marker. The core box labels should be completed using an indelible black marking pen. An example of recommended core box markings is given in Figure 3-22. The core box lid should have identical markings both inside and out, and both exterior ends of the box should be marked as shown. For angled borings, depths marked on core boxes and boring logs should be those measured along the axis of the boring. The angle and orientation of the boring should be noted on the core box and the boring log.

Care and Preservation of Rock Samples

A detailed discussion of sample preservation and transportation is presented in ASTM D 5079. Four levels of sample protection are identified:

- Routine care
- Special care
- Soil-like care
- Critical care

Most geotechnical explorations will use routine care in placing rock core in core boxes. ASTM D 5079 suggests enclosing the core in a loose-fitting polyethylene sleeve prior to placing the core in the core box. Special care is considered appropriate if the moisture state of the rock core (especially shale, claystone and siltstone) and the corresponding properties of the core may be affected by exposure. This same procedure can also apply if it is important to maintain fluids other than water in the sample. Critical care is needed to protect samples against shock and vibration or variations in temperature, or both. For soil-like care, samples should be treated as indicated in ASTM D 4220.

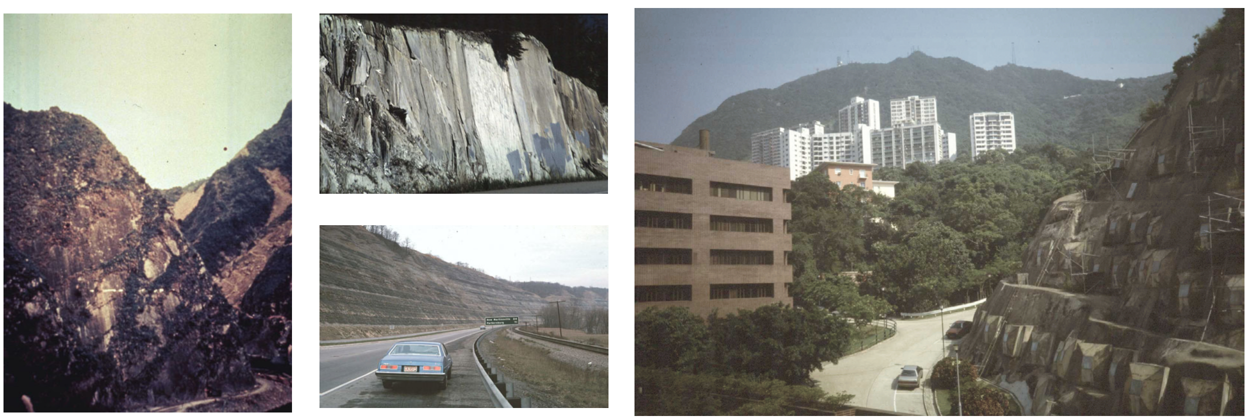


Figure 3-23. Rock Formations Showing Joints, Cut Slopes, Planes, and Stabilization Measures.

3.2.5 Geologic Mapping

Geologic mapping is briefly discussed here, with a more thorough review in FHWA Module 5 (Rock Slopes). Geologic mapping is the systematic collection of local, detailed geologic data, and, for engineering purposes, is used to characterize and document the condition of a rock mass or outcrop. The data derived from geologic mapping is a portion of the data required for design of a cut slope or for stabilization of an existing slope. Geologic mapping can often provide more extensive and less costly information than drilling. The guidelines presented are intended for rock and rock-like materials. Soil and soil-like materials, although occasionally mapped, are not considered in this section.

Qualified personnel trained in geology or engineering geology should perform the mapping or provide supervision and be responsible for the mapping activities and data collection. The first step in geologic mapping is to review and become familiar with the local and regional geology from published and non-published reports, maps and investigations. The mapping team should be knowledgeable of the rock units and structural and historical geologic aspects of the area. A team approach (minimum of two people, the "buddy system") is recommended for mapping as a safety precaution when mapping in isolated areas.

Procedures for mapping are outlined in an FHWA Manual (1989) on rock slope design, excavation and stabilization and in ASTM D 4879. The first reference describes the parameters to be considered when mapping for cut slope design, which include:

- Discontinuity type
- Discontinuity orientation
- Discontinuity in filling
- Surface properties
- Discontinuity spacing
- Persistence
- Other rock mass parameters

These parameters can be easily recorded on a structural mapping coding form shown in Figure 3-24. ASTM D 4879 also describes similar parameters and presents commonly used geologic symbols for mapping purposes. It also presents a suggested report outline. Presentation of discontinuity orientation data can be graphically plotted using stereographic projections. These projections are very useful in rock slope stability analyses. Chapter 3 (Graphical presentation of geological data) in the FHWA manual cited above describes the stereographic projection methods in detail.

3.3 BORING CLOSURE

All borings should be properly closed at the completion of the field exploration. This is typically required for safety considerations and to prevent cross contamination of soil strata and groundwater. Boring closure is particularly important for tunnel projects since an open borehole exposed during tunneling may lead to uncontrolled inflow of water or escape of compressed air.

In many parts of the country, methods to be used for the closure of boreholes are regulated by state agencies**.** National Cooperative Highway Research Program Report No. 378 (1995) titled "Recommended Guidelines for Sealing Geotechnical Holes" contains extensive information on sealing and grouting. The regulations in general, require that any time groundwater or contamination is encountered the borehole be grouted using a mixture of powdered bentonite, Portland cement and potable water. Some state agencies require grouting of all boreholes exceeding a certain depth. The geotechnical engineer and the field supervisor should be knowledgeable about local requirements prior to commencing the borings.

It is good practice to grout all boreholes. Holes in pavements and slabs should be filled with quick setting concrete, or with asphaltic concrete, as appropriate. Backfilling of boreholes is generally accomplished using a grout mixture . The grout mix is normally pumped though drill rods or other pipes inserted into the borehole. In boreholes filled with water or other drilling fluids the tremied grout will displace the drill fluid. Provisions should be made to collect and dispose of all displaced drill fluid and waste grout.

3.4 SAFETY GUIDELINES FOR GEOTECHNICAL BORINGS

All field personnel, including geologists, engineers, technicians, and drill crews, should be familiar with the general health and safety procedures, as well as any additional requirements of the project or governing agency.

Day Month Year

Date [ ] [ ] [ ] Inspector [ ]

Discontinuity data

Sheet No. [ ] of [ ]

NATURE AND ORIENTATION OF DISCONTINUITY

Station or No.	Type	Dip	Dip direction	Persistence	Aperture	Nature of filling	Strength of filling	Surface Roughness	Trend of lineation	Waviness wavelength	Waviness amplitude	Water/ Flow	Remarks

Type

0. Fault zone
1. Fault
2. Joint
3. Cleavage
4. Schistosity
5. Shear
6. Fissure
7. Tension crack
8. Foliation
9. Bedding

Persistence

1. Very low persistence <1 m
2. Low Persistence 1-3 m
3. Medium persistence 3-10 m
4. High persistence 10-20 m
5. Very high persistence >20 m

Aperture

1. Very tight (<0.1 mm)
2. Tight (0.1-0.25 mm)
3. Partly open (0.25-0.5 mm)
4. Open (0.5-2.5 mm)
5. Moderately wide (2.5-10 mm)
6. Wide (>10 mm)
7. Very wide (1-10 cm)
8. Extremely wide (10 - 100 cm)
9. Cavernous

Nature of filling

1. Clean
2. Surface staining
3. Non-cohesive
4. Inactive clay or clay matrix
5. Swelling clay or clay matrix
6. Cemented
7. Chlorite, talc, or gypsum
8. Others - specify

Compressive strength of infilling

		MPa
1.	Very strong rock	>200
2.	Strong rock	100-200
3.	Moderately strong rock	50-100
4.	Moderately weak rock	25-50
5.	Very weak rock	1-25
6.	Very stiff soil	0.6-1.0
7.	Stiff soil	0.15-0.6
8.	Firm soil	0.08-0.15
9.	Soft soil	0.04-0.08
10.	Very soft soil	<0.04

Roughness

1. Rough (or irregular), stepped
2. Smooth, stepped
3. Slickensided stepped
4. Rough (or irregular), undulating
5. Smooth, undulating
6. Slickensided, undulating
7. Rough (or irregular), planar
8. Smooth, planar
9. Slickensided

Water Flow (Infilled)

Seepage Rating	Description
I	The discontinuity is very tight and dry; water flow along it does not appear possible.
II	The discontinuity is dry with no evidence of water flow.
III	The discontinuity is dry but shows evidence of water flow, i.e. rust staining, etc.
IV	The discontinuity is damp but no free water is present.
V	The discontinuity shows seepage, occasional drops of water, but no continuous flow.
VI	The discontinuity shows a continuous flow of water (Estimate l/min and describe pressure, i.e. low, medium, high).

Water Flow (Filled)

- W1 The filling materials are heavily consolidated and dry; significant flow appears unlikely due to very low permeability.
- W2 The filling materials are damp, but no free water is present.
- W3 The filling materials are wet; occasional drops of water.
- W4 The filling materials show signs of outwash, continuous flow of water (estimate liters/minute).
- W5 The filling materials are washed out locally; considerable water flow along out-wash channels (estimate liters/minute and describe pressure, i.e. low, medium, high).

Figure 3-24. (a) Structural Mapping Coding Form for Discontinuity Survey Data.

ROCK MASS DESCRIPTION

GENERAL INFORMATION

Subdivision ☐ Km ☐ Date: Day ☐ Month ☐ Year ☐ Inspector ☐

Locality Type ☐

1. Natural exposure
2. Construction excavation
3. Trial pit
4. Trench
5. Adit
6. Tunnel

Slope Length ☐

Slope Height ☐

No. of supplementary sheets of discontinuity data ☐

Sketch ☐ Photograph ☐

0. No
1. Yes

SLOPE STABILITY ASSESSMENT

Inspection Rating ☐

1. **Urgent** - recent fall/visual evidence of significant movement - hazard
2. **Priority** - evidence of movement or change in conditions from previous years
3. **Observe** - identification of a specific area of potential instability
4. **OK** - no potential instability

Required Action ☐

1. **Inspect** - inspection required within the new three months approximately - state time
2. **Immediate Work** - stabilization work of specific location required in current year - state time
3. **Slow Order** - traffic at restricted speed/stopped/watchman until stabilization work carried out
4. **1-5 Years** - possible stabilization - state time
5. **Long-term** - substantial stabilization program
6. **No Action**

Assessment of Site Conditions

1. Open fractures indicative of past movement. ☐
2. Fractures oriented such that blocks could slide or topple on to the track. ☐
3. Evidence of recent movement. ☐
4. Probability that rockfall/slide would be of sufficient size to reach tracks and cause derailment. ☐
5. Serious consequence of derailment (e.g. track on narrow bench or supported by retaining wall). ☐

Remarks (consequences, stabilization, rockfalls, slide fence)

ROCK MATERIAL INFORMATION

Color ☐☐☐

1. Light
2. Dark

1. Pinkish
2. Reddish
3. Yellowish
4. Brownish
5. Olive
6. Greenish
7. Bluish
8. Greyish

1. Pink
2. Red
3. Yellow
4. Brown
5. Olive
6. Green
7. Blue
8. White
9. Grey
0. Black

Grain Size ☐

1. Very coarse (>60 mm)
2. Coarse (2-60 mm)
3. Medium (60 μ-20 mm)
4. Fine (2-60 μ)
5. Very fine (<2μ)

Compressive strength ☐

	MPa
1. Very strong rock	>200
2. Strong rock	100-200
3. Moderately strong rock	50-100
4. Moderately weak rock	25-50
5. Very weak rock	1-25
6. Very stiff soil	0.6-1.0
7. Stiff soil	0.15-0.6
8. Firm soil	0.08-0.15
9. Soft Soil	0.04-0.08
10. Very soft soil	<0.04

Method of determining compressive strength ☐

1. Measured
2. Assessed

Rock Type ☐

Qualifying terms to decribe rock

ROCK MASS INFORMATION

Fabric ☐

1. Blocky
2. Tabular
3. Columnar

Block size ☐

1. Very large (>8 m³)
2. Large (0.2-8 m³)
3. Medium (0.008-0.2 m³)
4. Small (0.0002-0.008 m³)
5. Very small (<0.0002 m³)

State of weathering ☐

1. Fresh
2. Slightly
3. Moderately
4. Highly
5. Completely
6. Residual soil

No. of major discontinuity sets ☐

LINE SURVEYS TO DETERMINE DISCONTINUITY SPACINGS

	Plunge of line	Trend of line	Length of line (m)	No. of fractures	Spacing	Remarks
Line 1						
Line 2						
Line 3						

Discontinuity spacing

1. Extremely close (<20 mm)
2. Very close (20-60 mm)
3. Close (60-200 mm)
4. Moderate (200-600 mm)
5. Wide (600-2000 mm)
6. Very wide (2000-60000 mm)
7. Ext. Wide (>6000 mm)

Figure 3-24. (b) Structural Mapping Coding Form for Slope Assessment.

Typical safety guidelines for drilling into soil and rock are presented in Appendix A. Minimum protective gear for all personnel should include hard hat, safety boots, eye protection, and gloves.

It is not unusual to encounter unknown or unexpected environmental problems during a site investigation. For example, discolored soils or rock fragments from prior spills, or contaminated groundwater may be detected. The geotechnical engineer and the field supervisor should attempt to identify possible contamination sources prior to initiating fieldwork. Based on this evaluation, a decision should be made whether a site safety plan should be prepared. Environmental problems can adversely affect investigation schedules and cost, and may require the obtaining of permits from State or Federal agencies prior to drilling or sampling.

At geotechnical exploration sites where unknown or unexpected contamination is found during the fieldwork, the following steps should be taken:

1. The field supervisor should immediately stop drilling and notify the geotechnical engineer. The field supervisor should identify the evidence of contamination, the depth of contamination, and the estimated depth to the water table (if known). If liquid-phase product is encountered (at or above the water table), the boring should be abandoned immediately and sealed with hydrated bentonite chips or grout.

2. The project manager should advise the environmental officer of the governing agency and decide if special health and safety protocol should be implemented. Initial actions may require demobilization from the site.

3.5 COMMON SENSE DRILLING

Drillers performance is commonly judged by the quantity of production rather than the quality of the borings and samples. Not surprisingly, similar problems develop throughout the country. All geotechnical engineers and field supervisors need to be trained to recognize these problems, and to assure that field information and samples are properly obtained. The following is a partial listing of common errors:

- Not properly cleaning slough and cuttings from the bottom of the bore hole. The driller should not sample through slough, but should re-enter the boring and remove the slough before proceeding.

- In cohesionless soils, jetting should not be used to advance a split barrel sampler to the bottom of the boring.

- Poor sample recovery due to use of improper sampling equipment or procedures.

- When sampling soft or non-cohesive soils with thin wall tube samplers (i.e., Shelby tube) it may not be possible to recover an undisturbed sample because the sample will not stay in the barrel. The driller should be clearly instructed not to force recovery by overdriving the sampling barrel to grab a sample.

- Improper sample types or insufficient quantity of samples. The driller should be given clear instructions regarding the sample frequency and types of samples required. The field supervisor must keep track of the depth of the borings at all stages of the exploration to confirm proper sampling of the soil and/or rock formations.

- Improper hole stabilization. Rotary wash borings and hollow-stem auger borings below the groundwater level require a head of water to be maintained at the top of the casing/augers at all times. When the drill rods are withdrawn or as the hollow stem auger is advanced, this water level will tend to drop, and must be maintained by the addition of more drilling fluid. Without this precaution, the sides of the boring may collapse or the bottom of the boring may heave.

C Sampler rods lowered into the boring with pipe wrenches rather than hoisting plug. The rods may be inclined and the sampler can hit the boring walls, filling the sampler with debris.

C Improper procedures while performing Standard Penetration Tests. The field supervisor and driller must assure that the proper weight and hammer drop are being used, and that friction at the cathead and along any hammer guides is minimized.

Figure 3-25. Views of Rotary Drill Rigs Mounted on Trucks for Soil & Rock Exploration.