PIT SLOPE MANUAL

supplement 3-5

SAMPLING AND SPECIMEN PREPARATION

This supplement has been prepared as part of the

PIT SLOPE PROJECT

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THE PIT SLOPE MANUAL

The Pit Slope Manual consists of ten chapters, published separately. Most chapters have supplements, also published separately. The ten chapters are:

1. Summary
2. Structural Geology
3. Mechanical Properties
4. Groundwater
5. Design
6. Mechanical Support
7. Perimeter Blasting
8. Monitoring
9. Waste Embankments
10. Environmental Planning

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ABSTRACT

Sampling is influenced by geology and geography of a mine site, and by the requirements of design. Rock samples are usually obtained by coring with diamond drills or occasionally by removing surface blocks. Soil can be sampled by auger or, if undisturbed samples are required, by tube sampler. Undisturbed samples of cohesive soil can also be obtained by cutting blocks of soil from the side or bottom of a trench.

Rock specimens for triaxial testing must be carefully ground to produce parallel, flat ends to a close tolerance. Shear box specimens are carefully aligned and then grouted into the shear box. "Undisturbed" soil specimens can be cut from field samples with special tools; however some disturbance is inevitable. Clay specimens must be protected from drying.

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M. Gyenge and G. Herget were responsible for this chapter. Address enquiries to them at: 555 Booth Street, Ottawa, K1A 0G1, Canada.

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The Pit Slope Group consisted of D.F. Coates*, M. Gyenge*, G. Herget, B. Hoare, G. Larocque, D.R. Murray, R. Sage* and M. Service.

* successive Pit Slope Group Leaders.

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SAMPLING PROCEDURES

INTRODUCTION

1. Sampling of subsurface materials comprises complex techniques which include many different procedures. These are influenced by geological and geographical conditions, by the purpose of the investigation, and by given specific conditions, such as accessibility of the test site, or the availability of appropriate test samples at the various stages of mine development. A subsurface investigation should provide a sufficient number of soil and rock samples of a quality which will enable adequate testing for determining the mechanical properties pertinent to the proposed design.

2. Sampling and sample handling procedures for soils and rocks are described in several ASTM Standards, referred to in subsequent paragraphs. The relevant procedures are also summarized in ASTM Designation D 420-69 (1).

3. Laboratory tests are performed on samples which are sufficiently representative of the entire rock mass. The test specimen should be free of cracks and other weaknesses when the strength and deformation properties of an intact rock material are needed. On the other hand shear testing of discontinuities requires specimens which contain the specific discontinuity being tested. Sampling of disintegrated or highly altered rocks and of soil overburden follows practices developed in the field of soil mechanics.

4. Sampling of a rock to determine the characteristics of the substance itself or of a plane of weakness can be done using core or block samples.

5. Core samples can be obtained, either surficially or in a deep borehole, by using a rotary drill with a core barrel and diamond bit. The advantage of core samples is that they can be drilled at specified locations, directions, and depths. The depth is particularly important when specimens of rock are needed from various elevations.

6. Core specimens are frequently obtained from block samples by means of laboratory diamond drilling. Block samples are also used for testing the shear strengths of discontinuities. Blocks containing the relevant discontinuity are collected for this purpose. For certain types of tests, such as porosity or density, and point load strength index, lump samples are satisfactory. In these cases, samples of the geologic formation are gathered randomly. Some of the tests dealing with broken or soil-like material require bulk samples of a given quantity; these are also obtained by random sampling.

ROCK SAMPLING

Conventional Diamond Core Drilling

7. Conventional diamond core drilling is used to obtain intact samples of rocks, and of soils which are too hard for soil sampling methods. The procedure of diamond core drilling is described in ASTM Designation D 2113-70. This standard is primarily intended for obtaining data about the in situ condition of the formation, and for obtaining core samples for laboratory testing (2).

8. A wide variety of rotary drilling equipment is manufactured, varying in terms of driving and feed mechanisms used, capacity, as well as hole sizes and depths that can be drilled. Accessories for such a rig include:

a. The water or drilling mud pump, or air compressor used for circulating the coolant to the bit and for flushing the hole; they must be capable of delivering a sufficient volume at sufficient pressure to satisfy the requirements of the hole size.
b. The core barrels of which there are two principal types - the single tube and the double tube. The single tube type consists of a hollow steel tube, with a head at its upper end threaded for attaching to the drill rod; it is fitted at its lower end with a blank or a set reaming shell, a core lifter, and a core bit. The double tube type has an additional concentric inner tube, supported by a swivel at the head so that it can remain stationary while the outer tube rotates. The single tube type is used primarily to sample hard, solid rocks, which require a diamond drill bit. The double tube type is used to sample fractured rocks. It may be used to obtain cores in hard, brittle or partially cemented soils, and also for cores of soft, weakly cemented rocks. For these materials, hardened metal drill bits and shorter core barrels are used.
c. The core bits are set with diamonds or faced with tungsten carbide, or with similar hard materials appropriate for the materials drilled. The dimensions of standard size bits and core barrels are given in Table 1. In specific cases, bits and core barrels larger than standard size might also be used. For example, the aim of the core drilling illustrated in Fig 1 to 7, was to obtain 9.5 in. (24.13 cm) diameter cores required for investigating the effect of specimen size on the strength and deformation properties of the rock.
d. The drive pipe is used for penetrating the overburden soils into bedrock. The pipe should be of a diameter which will allow the core barrel to pass through it.
e. The casing is used when required for lining sections of the hole in loose material or in unconsolidated ground. The casing should be dimensioned to permit the use of the next smaller bit and core barrel. The dimensions of standard casings are given in Table 1.
f. The hollow drill rods have diameters as given in Table 1.
g. The auxiliary equipment includes roller bits, fishtail bits, wrenches, equipment for mixing the drilling mud, a cathead winch and derrick for driving the casing and for hoisting and lowering the drill rods.
h. The core boxes of wood or other durable material are for the protection and storage of cores. The boxes should be provided with longitudinal spacers, forming separate compartments for each core run. Small blocks which fit between the spacers should also be provided to mark the beginning and end of each core run.

9. The cores provide information on the composition and condition of the different rock formations, with evidence on the spacing and condition of the joints, seams, fissures, and other structural details. The accuracy and dependability of the records provided by diamond drilling rests to a large extent upon the size of the core in relation to the kind of material being drilled, the percentage of core recovery, the behaviour of the material during drilling, and upon the experience of the drill crew. Recovery of core is much more important than rapid progress in drilling. To increase recovery, it is important to use the largest practicable bit

Table 1: General particulars of rods, casing and core barrels

Size	Rod					Casing				Core barrel							Nominal diameter			
	Desig-nation	O.D.		Coupling I.D.		O.D.		Coupling I.D.		Desig-nation	Core bit set				Reaming shell		Hole		Core	
											O.D.		I.D.		O.D.					
		in.	mm	in.	mm	in.	mm	in.	mm		in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
EX	EW	1.375	34.92	0.437	11.11	1.812	46.02	1.500	38.10	EWX or EWM	1.470	37.34	0.845	21.46	1.485	37.72	$1\frac{1}{2}$	38.1	$\frac{13}{16}$	20.6
AX	AW	1.750	44.45	0.625	15.88	2.250	57.15	1.906	48.41	AWX or AWM	1.875	47.62	1.185	30.10	1.890	48.01	$1\frac{15}{16}$	49.2	$1\frac{3}{16}$	30.2
BX	BW	2.125	53.98	0.750	19.05	2.875	73.02	2.375	60.32	BWX or BWM	2.345	59.56	1.655	42.04	2.360	59.94	$2\frac{3}{8}$	60.3	$1\frac{5}{8}$	41.3
NX	NW	2.625	66.68	1.375	34.92	3.500	88.90	3.000	76.20	NWX or NWM	2.965	75.31	2.155	54.74	2.980	75.69	3	76.2	$2\frac{1}{8}$	54.0
HX	HW	3.500	88.90	2.375	60.32	4.500	114.30	3.937	100.00	HWX or HWF	3.890	98.81	3.000	76.20	3.906	99.21	$3\frac{15}{16}$	100.0	3	76.2

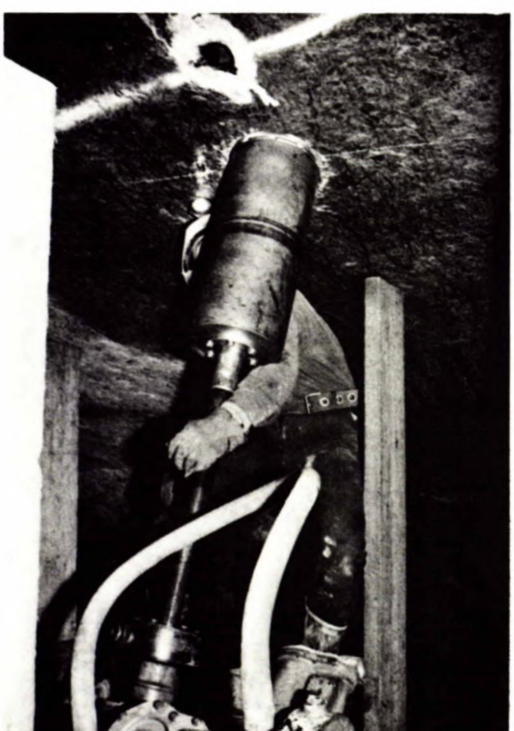


Fig 1 - Collaring a 9.5 in. (24.13 cm) diameter diamond drill hole. A crew member supports the slow-turning core barrel on his shoulder while starting.

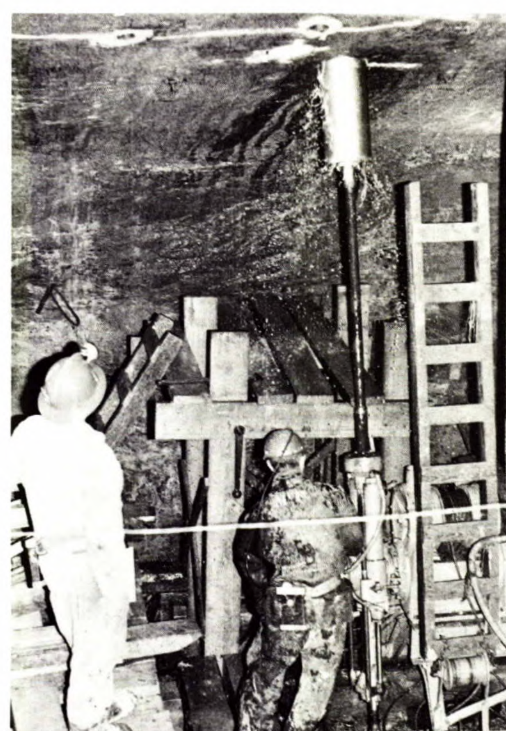


Fig 2 - Drilling a 9.5 in. (24.13 cm) diameter drill hole. After starting rotation speed and bit pressure at the optimum values for the given condition.

diameter and core barrel.

10. The diamond core drilling procedure, undertaken to obtain 9.5 in. (24.13 cm) diameter by 24 in. (61 cm) long cores, is demonstrated by the following series of photographs:

a. Figure 1 illustrates the slow-turning core barrel; it is supported on the shoulder of a crew member until the hole is collared ie, until a shallow circular annulus is drilled into the rock face. This is performed without the use of water.

b. The drill water is then turned on and rotation speed increased to the optimum for the given conditions. The optimum rotation speed varies with the type of bit, the diameter of core barrel, and the type of rock. Excessive rotation speeds will result in rapid bit wear and will also break off the core. Finally, the bit pressure is adjusted by the hydraulic feed mechanism on the drilling machine and coring is started (Fig 2). Bit pressure must be carefully adjusted because excessive pressure will cause the bit to plug, and may shear the core.

c. After the run is completed ie, when a core length equal to that of the core barrel has been drilled, the barrel is retrieved (Fig 3). The drilled core still attached to the host rock at its base is shown in Fig 4.

d. The core is freed from its base with the help of a steel wedge. The wedge is driven into the annular slot drilled around the core. Due to the bending moment thus created, and hence to the induced tensile stresses, the core breaks at its base. The freed core, while continuously supported at its near end, is carefully extracted (Fig 5 and 6).

e. The 9.5 in. (24.13 cm) diam. x 22 in. (55.9 cm)

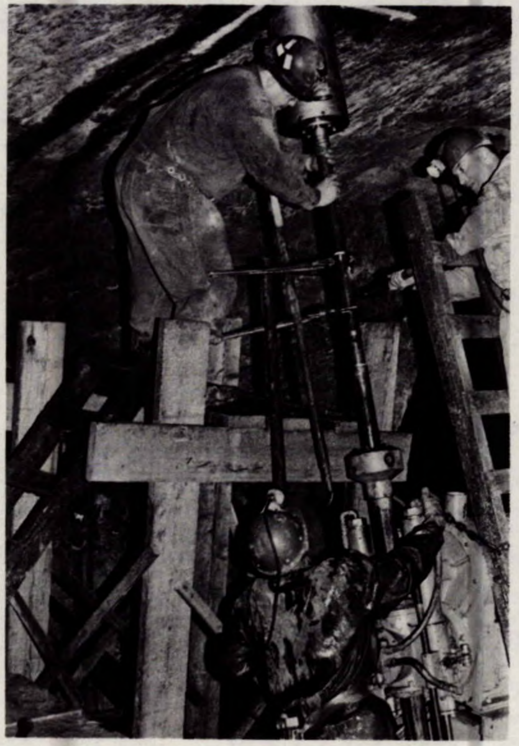


Fig 3 - Retrieving the core barrel, following completion of the run.

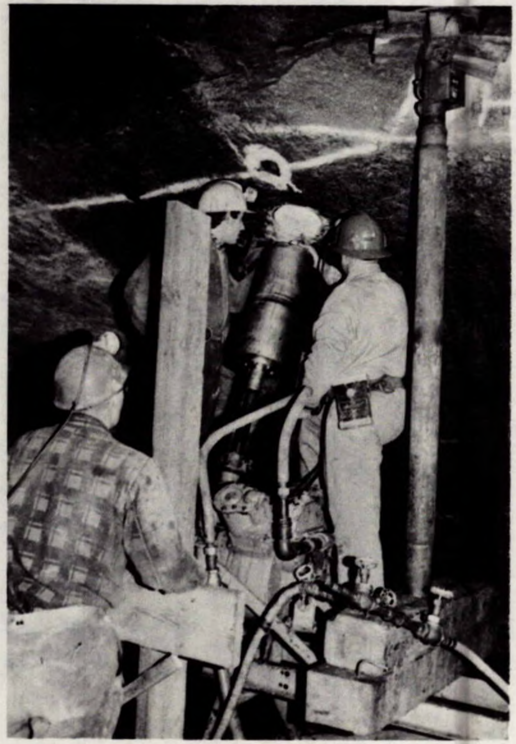


Fig 4 - Core still attached to the host rock at its base.

Fig 5 - Extracting the core, while continuously supporting its end.

Fig 6 - Extracted core.

core, together with the core barrel, is shown in Fig 7.

11. Due to their high cost, cores larger than the standard NX size are drilled for specific purposes only and then usually only to shallow depths, say to about 15 ft (4.6 m). Normally, NX cores are preferred for testing purposes; BX cores are also frequently used. The vertical set-up of a rotary drill is shown in Fig 8, using NX bits and core barrels. In this case the lengths of the core barrels and drill rods are restricted by the head room. Regular length core barrels and drill rods are used in Fig 9, illustrating the drilling of a BX core in a horizontal direction.

12. The core is placed in a core box, with the first segment in the left hand side of the upper compartment, and proceeding in the same manner to the next lower compartment, and so on, until the box is full; each box is filled with core starting at its left end. The depths of the top and bottom of each core segment, as well as of each noticeable gap in the rock formation, are marked by clearly labelled spacer blocks. Delicate

Fig 7 - A 22 in. (55.9 cm) long 9.5 in. (24.13 cm) diameter core with the core barrel.

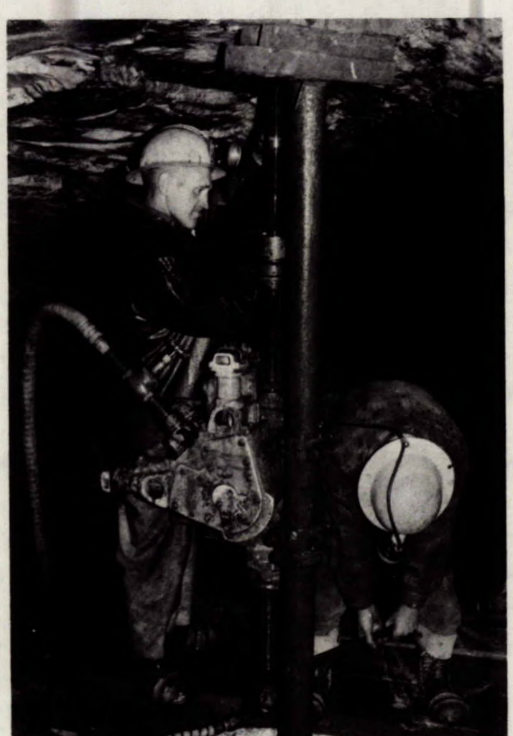


Fig 8 - Vertical set-up of a rotary drill using NX size bit and core barrel.

cores, or ones which tend to alter materially upon drying, are wrapped in a plastic sheet or sealed in wax, or both, whenever necessary.

13. Since one of the important purposes of diamond drilling is to obtain information on the composition, condition, and structure of the rock mass, the relevant data are recorded by core logging (Fig 10). This record includes the following:

a. length of each core run and the length, or percentage, or both, of the core recovered
b. description of the rock in each run
c. rock structure, including the prevalent stratification, angle of dip, cavities, fissures, defects, and any other observations which provide information about these features
d. depth, thickness and apparent nature of the filling material found in each cavity or soft seam of the rock.

Core Sampling of Discontinuities

14. To obtain samples of selected discontinuities, drilling must be undertaken in such a way

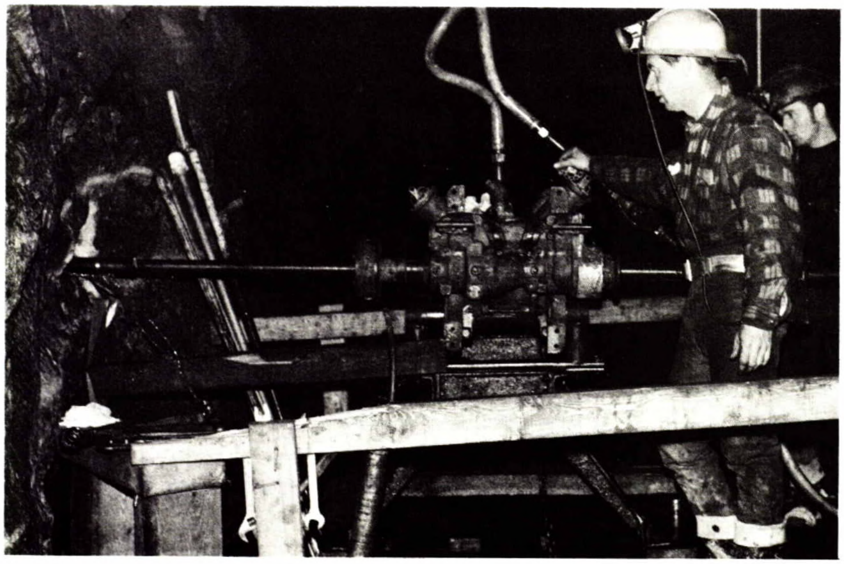


Fig 9 - Drilling BX size core in horizontal direction.

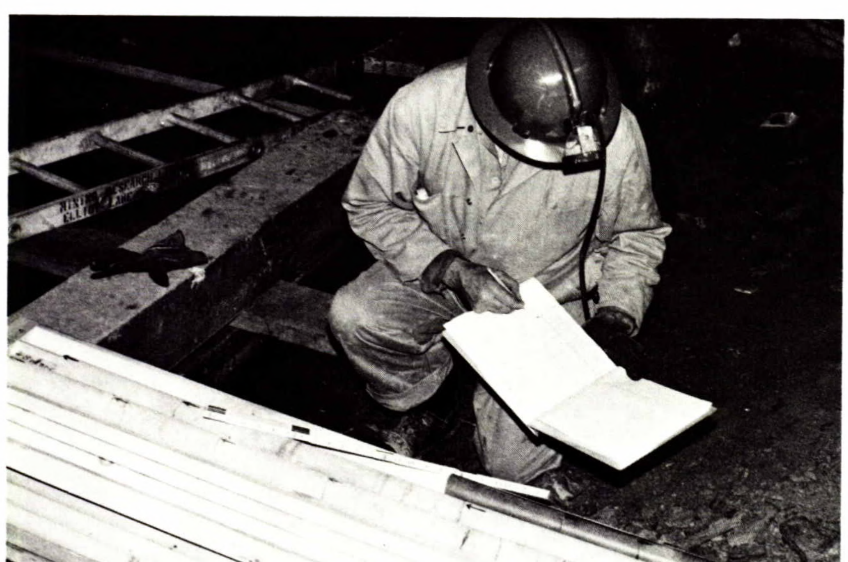


Fig 10 - Relevant data are recorded by core logging.

that the discontinuity is contained within the core. The coring equipment satisfying such requirements should be:

a. strong enough to drill large-diameter cores, up to 10 in. (25.4 cm) in diameter, in the greatest possible variety of rock types,
b. portable, so that it can sample discontinuities in the widest possible variety of places otherwise inaccessible to a vehicle,
c. self-supporting, which means that it can be anchored to a wall of any inclination,
d. powered by a portable unit, so that it is independent of a stationary source of power.

15. All these requirements are satisfied by the portable coring unit shown in Fig 11. All parts of the disassembled unit can be carried by two men. The unit consists of the following parts:

a. Base, provided with two wheels for easier transport and with four screws for four-point support; the base contains two holes through which the whole unit is anchored to a rock face.
b. Stem, fixed perpendicularly to the base, with teeth to provide support for the moving parts.
c. Feed gear assembly which supports the motor and provides for forward and backward movement of the core barrel along the stem.
d. Motor, in this case a 6 HP gasoline engine mounted upon the feed gear assembly.
e. Core barrel with diamond bits, connected to the motor; it is convenient to stock a set of core barrels with different internal diameters, ranging from about 4 to 10 in. (10.2 to 25.4 cm) for use in rocks of varying hardness; one of the available core barrels should be of the double barrel type for drilling in extensively fissured rocks.
f. Water pump, for supplying water to the inner part of the barrel as the drilling is always wet.

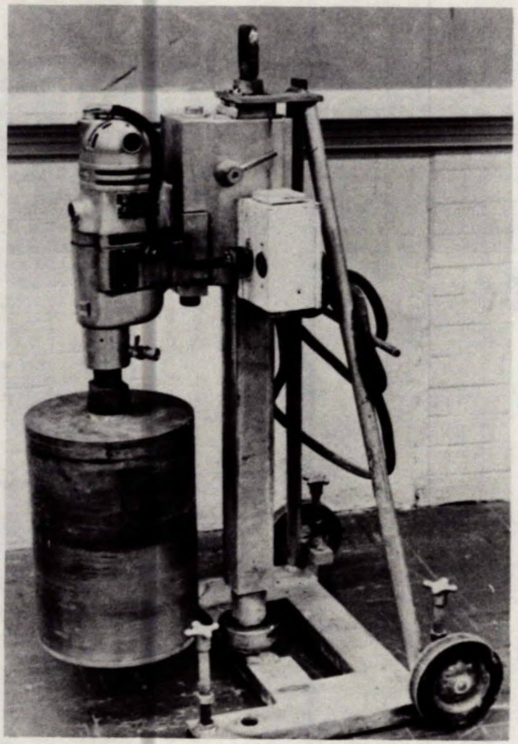


Fig 11 - Portable coring unit.

g. Guides for reducing vibration of the core barrel during drilling; three of these are adjustably attached to the base and are provided with wheels, so they can be kept in contact with the rotating barrel.

h. Electric power unit, for supplying power to the water pump and electric hammer; in this case the unit is a portable generator, powered by a small gasoline engine with a maximum output of 5 kilowatts.

16. The coring procedure consists of the following steps:

a. selection of location. The choice is usually based upon the type of discontinuity to be tested. The coring position is chosen so that the largest possible extent of the weakness plane is incorporated in the core; accessibility and availability of two sound and crack-free areas for fixing the anchors are further requirements in selecting the drilling location.

b. drilling of anchor holes. In most rock types it is sufficient to use self-drilling concrete anchors for rock bolts; they are usually 3 in. (7.6 cm) long and 0.5 in. (1.3 cm) in diameter; a hole of corresponding size is drilled by an electric hammer, then cleaned and the bolt driven into it; care has to be taken to ensure that the positions of the two holes correspond with those of the two in the base of the coring unit.

c. anchoring the base. This is done by screwing the base to the anchors with long bolts; due to the irregular surface of the rock face, washers are often necessary to fill the space between the base and the rock; to ensure a firm support against the wall, the screws provided at the four corners of the base are extended until they make contact with the supporting rock wall.

d. mounting the drill. The gasoline engine is fixed first to the feed gear assembly, the core barrel is then screwed to the axis of the motor and finally, the water pipe is connected to the core barrel.

e. drilling. Before drilling, the three anti-vibrating guides are brought into contact with the barrel; the water supply is turned on, and drilling started, Fig 12; the entire drilling proceeds at a rate which depends on the size of the core barrel and on the hardness of the rock; generally the rate varies between 2 in. and 0.25 in. (5.1 cm and 0.64 cm) per minute.

f. recovery of sample. The core must be broken off at its base from the surrounding mass unless there is a favorably orientated discontinuity at the bottom end; this can be done using a chisel and hammer; the wedge shaped chisel is driven into the slot formed by drilling; the bending moment produced along the base of the core usually causes a split which frees the core; if the core is drilled along a discontinuity, it can usually only be taken out of the hole in two pieces; in case of a closed and tight joint, the core can be extracted in one piece (Fig 13); if in several pieces, then as in Fig 14 and 15, care must be taken to ensure that all core parts are retained and that they are assembled in their original positions.

17. The different pieces of the assembled core are properly labelled and wired together Figs 14(a) and 15. Unless the core is to be tested immediately, it is wrapped in a plastic bag for protection.

Block Sampling

18. Block samples can be obtained from outcrops, or from the walls and bottom of an excavation, wherever it may be possible to loosen sufficient amounts of rock. Block sampling is always easier than coring. No special equipment is required other than a pick and shovel.

19. Block sampling can be used only if testing of the exposed surface rock is judged acceptable and adequate. Block samples can offer economic advantages even in cases where the testing method calls for cylindrical specimens. The total cost of obtaining cylindrical specimens from block samples in the laboratory is considerably less than the cost of producing a similar number of specimens by field drilling.

Fig 12 - Portable coring unit in operation.

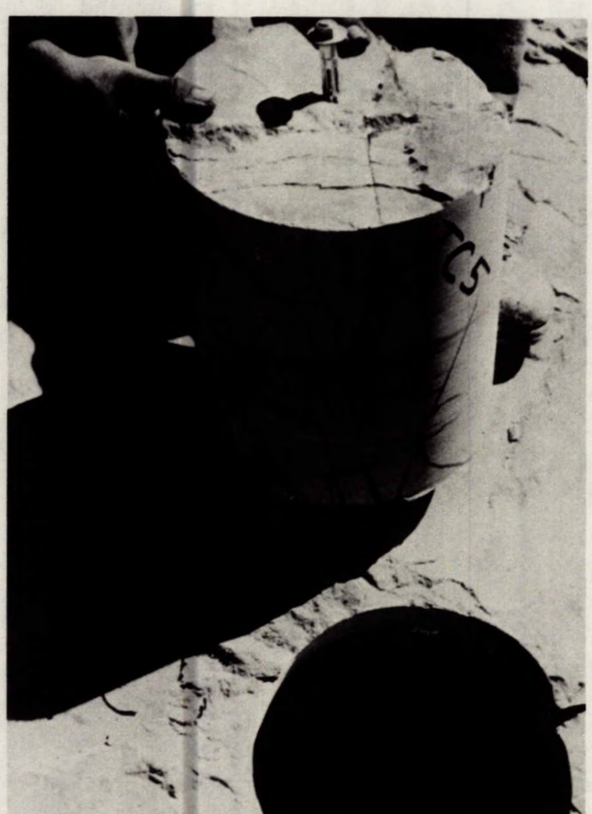
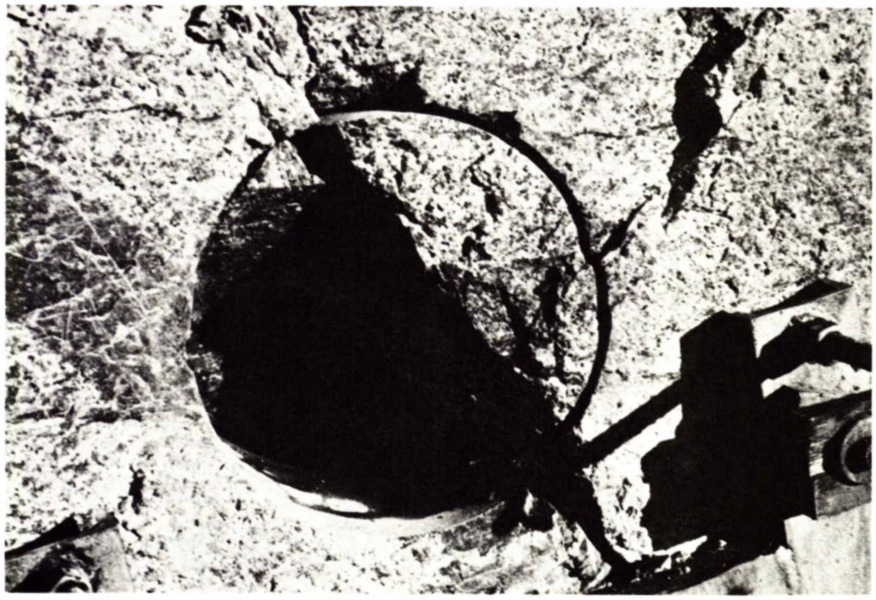


Fig 13 - Core extracted in one piece, joints are closed and tight.



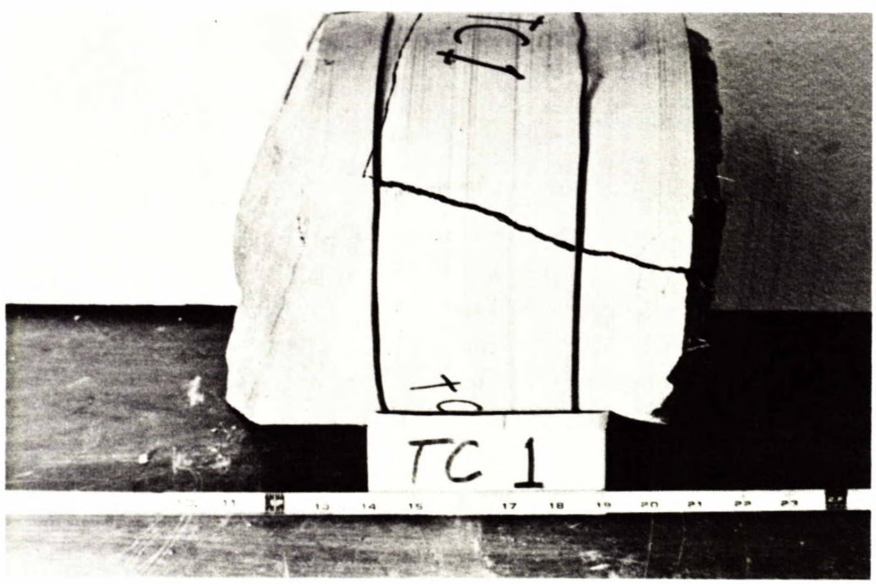


Fig 14 - Core extracted in several pieces: -(a) rock face after removing one piece of the drilled core; (b) core pieces assembled and wired together.

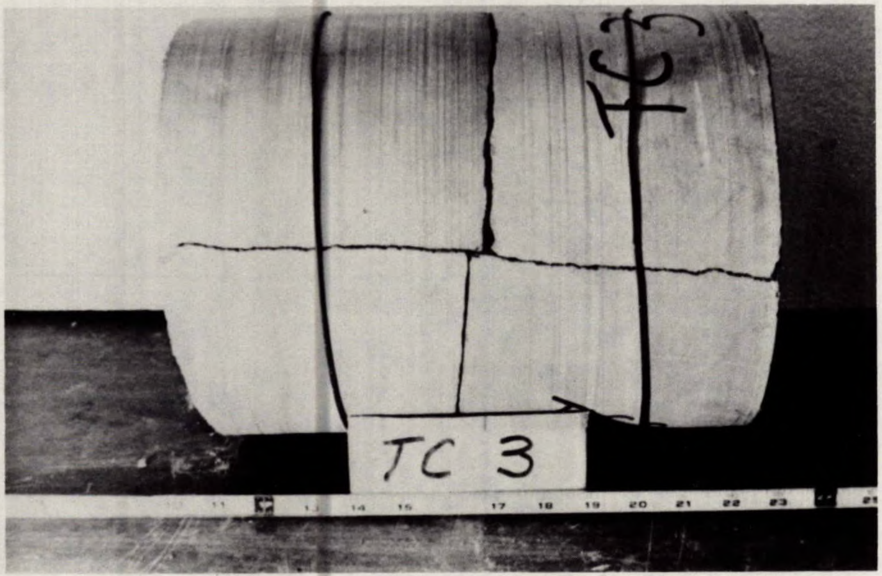


Fig 15 - Pieces of core are properly labelled; following assembling and wiring.

20. The selected block samples are properly marked to include the in situ orientation of the block wherever this is essential. The blocks are individually wrapped in plastic bags for proper protection. If maintaining the natural moisture content of the sample is important, they are also covered by damp cloths. Delicate samples which may alter materially upon drying, might have to be sealed in wax.

21. The two halves of the samples which contain the discontinuity are assembled, properly labelled, and wired together before being wrapped (Fig 16).

SOIL SAMPLING

For Remoulded Specimens

22. Auger boring provides the simplest method of investigating and sampling soil. It may be used for testing disturbed samples as in cases of grain size analysis, consistency limits, etc. The method is described in ASTM Designation D 1452-65 (3).

23. The depths of auger investigations are limited by the groundwater table and by the amount and size of the gravel and boulders encountered.

24. Hand operated helical augers 1.5 to 4 in. (3.8 to 10.2 cm) in diameter and posthole augers 2 to 12 in. (5.1 to 30.5 cm) can be used for depths up to about 20 ft (6.1 m). With the aid of a tripod holes of up to 80 ft (24.4 m) can be sampled.

25. There are three types of machine-driven augers:

a. helical augers, 3 to 16 in. (7.6 to 40.6 cm) in diameter,
b. disk augers, up to 42 in. (106.7 cm) in diameter,
c. bucket augers, up to 48 in. (121.9 cm) in diameter.

26. An auger boring is made by turning the auger the desired distance into the soil, withdrawing it, and removing the soil for examination and sampling. It is again inserted into the hole, and the process repeated. Pipe casing is required in unstable soils, and especially where the boring

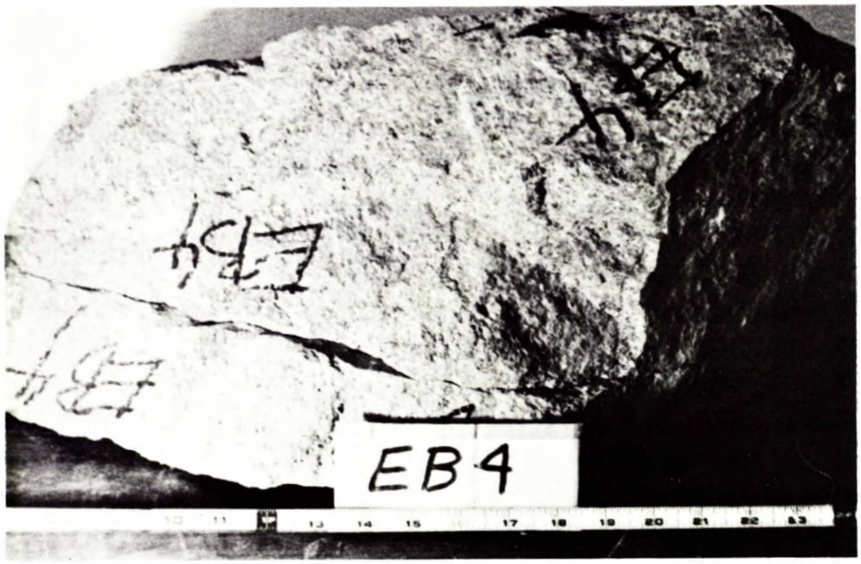


Fig 16 - Block sample with discontinuity; halves are matched, assembled and properly labelled.

is extended below the groundwater level. The inside diameter of the casing must be slightly larger than the diameter of the auger.

27. The auger can be used both for boring the hole and for extracting disturbed samples of soils. Rock fragments larger than one-tenth of the diameter of the hole cannot be successfully removed by normal augering methods.

28. Each sample should be sealed in a jar or other airtight container, and properly labelled. The containers, made of glass, metal or plastic, should have a capacity of 4 to 8 fluid-oz (118 to 237 cm^3).

29. Stout cloth or plastic bags, with a capacity of at least 35 lb (16 kg) are required for bulk sampling soils. A 6 by 6 ft (1.8 by 1.8 m) sheet of canvas is useful for examining the soil samples, and for preparing bulk soil samples by mixing.

For Undisturbed Specimens

30. Undisturbed soil specimens are required analyzing the stability of an overburden consisting of cohesive earth materials. The term "undisturbed specimen" refers to a soil specimen taken in such a way that its original structure and water content are preserved.

31. The best undisturbed clay samples can be obtained by carefully cutting blocks from the bottom or walls of a trench excavated for the purpose. Such block samples are protected against moisture loss by a wax coating. During transport to the laboratory they are protected by appropriate packaging eg, wooden boxes. In the laboratory the samples are kept in a controlled environment. The specimens required for testing for triaxial or direct shear are obtained from the block samples by trimming.

32. Block sampling is limited to shallow depths and to cases in which the trench can be easily dewatered. In all other cases, undisturbed samples can be obtained only by tube sampling with thin-walled metal tube samplers.

33. These are of two general types namely, open tube, and piston samplers. In general, the piston samplers are better because they can be

used in almost all types of soil.

34. The general requirements for thin-walled tube sampling are described in ASTM Designation D 1587-67 (4); when details are given of the apparatus, drilling equipment, sizes of tubes, sealing wax and accessories required, sampling procedures, preparation for shipment, and reporting. Additional requirements and a description of the piston samplers are given by Hvorslev (5).

SPECIMEN PREPARATION PROCEDURES

INTRODUCTION

35. The rock or soil samples obtained in the field are stored and handled in a manner which will ensure the most reliable test results. For certain tests natural, undisturbed specimens only are acceptable; for others, even completely disturbed specimens may be used.

36. The tests require specimens of a certain specified size, shape, and number. These requirements are listed for each type of test in the descriptions given in Supplements 3-1, 3-2 and 3-4. For ready reference the requirements are also summarized here.

37. From the representative samples collected in the field the specimens are prepared in the laboratory. Specimen preparation includes complex techniques in many types of procedures. These are governed by the purposes of the tests, types of materials tested, type of collected field samples, availability of equipment, and tools required for preparation. Procedures described here for preparing rock specimens are based on practices developed within the CANMET Mining Research Laboratories. They are given only to facilitate understanding. Their listing neither implies CANMET's endorsement of such equipment and tools nor does it represent standards for specimen preparation procedures. The reader is encouraged to seek alternatives for preparation and for equipment which might best suit specific requirements.

38. Specimen preparation procedures for tests which have been standardized by the American Society for Testing and Materials are not reproduced within this Supplement, but are listed in references.

SPECIMEN REQUIREMENTS

39. The laboratory tests are described in the following supplements:

Supplement 3-1, Laboratory classification tests;

Supplement 3-2, Laboratory tests for design parameters;

Supplement 3-4, Selected soil tests.

40. The required shapes, sizes and numbers of rock specimens, are summarized in Table 2.

41. Similar information about laboratory soil testing is given in Table 3.

SPECIFIC REQUIREMENTS

42. Requirements as to the shape and size of the rock specimens listed in Table 2, are similar for several tests. There are however certain requirements which are specific in some cases. These must be borne in mind during the sampling or during the storage and handling of samples and specimens.

43. For determining water content, porosity and density of rock specimens, a representative

Table 2: Summary of specimen requirements for laboratory rock testing

Test	Sample	Specimen: Shape	Dimensions or weight: Imp. unit	Dimensions or weight: SI unit	Minimum number for each sample	Supplement of test description
Water content	Lump	Irregular		~ 50g each	5	3-1
Porosity / density	Lump	Irregular	Suitable		5	3-1
Swelling pressure and swelling strain index	Core	Disc	$L_o > 0.5$ in.; $D \geq 2.5\ L_o$; $L_o > 10$ G	$L_o > 13$ mm	3	3-1
Slake - durability index	Lump	Irregular		~ 50g each	10	3-1
Point load strength index	Core	Cylindrical	AX to PX		10	3-1
	Lump	Irregular (~ spheroid)	D ~ 2 in. (1 to 4 in.)	D ~ 54 mm (25 to 100 mm)	20	
Uniaxial compressive strength	Core	Cylindrical	$D \geq$ NX; $L_o = 2.5$ D to 3.0 D; $D > 10$ G		3	3-1
Tensile strength	Core	Disc	D = NX; t = 0.5 in.	t = 12.7 mm	10	3-1
Elastic modulus and Poisson's ratio	Core	Cylindrical	$D \geq$ NX; $L_o = 2.5$ D to 3.0 D; $D > 10$ G		3	3-2
Ultrasonic elastic constants	Core	Cylindrical	$D \geq$ AX; L_o = see Fig 10 in Suppl. 3-2		3	3-2
Triaxial compressive strength	Core	Cylindrical	$D \geq$ NX; $L_o = 2.5$ D to 3.0 D; $D > 10$ G		3	3-2
Residual angle of friction	Core or block	Cylindrical or irregular, halved by saw-cut plane	Saw-cut plane; Length $\geq$ 3 in.; Width $\geq$ 2 in.	$\geq$ 7.6 cm; $\geq$ 5.4 cm	3	3-2
Strength of discontinuity by direct shear test	Core or block	Cylindrical or irregular, halved by discontinuity plane	Discontinuity plane; Length $\geq$ 3 in.; Width $\geq$ 2 in.	$\geq$ 7.6 cm; $\geq$ 5.4 cm	3	3-2
Strength of discontinuity by triaxial test	Core	Cylindrical with discontinuity plane inclined at 25° to 40° to the axis	$D \geq$ NX; $L_o = 2.0$ D to 2.5 D		2	3-2
Strength of crushed rock material	Bulk	Cylindrical, recompacted	$D \geq$ 2 in.; $L_o = 2.0$ to 2.5 D; $D > 10$ G	$D \geq$ 54 mm	2	3-2
Time - dependent properties	Core	Cylindrical	$D \geq$ NX; L = 2.5 D to 3.0 D; $D > 10$ G		15	3-2

Legend:

D = diameter of cylindrical specimen

L_o = length or height of cylindrical specimen

G = largest grain diameter

t = thickness of disc specimen

$\geq$ = preferably not less than

Table 3: Summary of specimen requirements for laboratory soil testing

<table>
<tr><th rowspan="3">Test</th><th rowspan="3">Sample</th><th colspan="4">Specimen</th><th rowspan="3">Supplement of test description</th></tr>
<tr><th rowspan="2">Shape</th><th colspan="2">Dimensions or weight</th><th rowspan="2">Minimum number for each sample</th></tr>
<tr><th>Imp. unit</th><th>SI unit</th></tr>
<tr><td>Grain size analysis
A. Material retained on No. 10 (2 mm) sieve:
Gravelly soils
Sandy soils
Silt and clay soils
B. Material passing No. 10 (2 mm) sieve
Sandy soils
Silt and clay soils</td><td>Bulk (disturbed)</td><td>Loose, separated into particals</td><td>

8.8 to 22.0 lb
3.3 lb
0.9 lb</td><td>

4 to 10 kg
1.5 kg
0.4 kg

115 g
65 g</td><td></td><td>3 - 4</td></tr>
<tr><td>Consistency limits
Liquid limits
Plastic limit
Shrinkage limit</td><td>Lump (disturbed)
G < 0.42 mm (Sieve No. 40)</td><td>Mixed with water</td><td></td><td>100 g
15 g
30 g</td><td></td><td>3 - 4</td></tr>
<tr><td>Moisture - desity relationship</td><td>Bulk (disturbed)</td><td>Cylindrical, recompacted</td><td>D = 1.313 in.
L_o = 2.816 in.
G 4.75 mm (No. 4 sieve)</td><td>33.35 cm
71.53 cm</td><td>3</td><td>3 - 4</td></tr>
<tr><td rowspan="2">Triaxial compression test</td><td>Undisturbed</td><td>Cylindrical, trimmed</td><td>D = 1.4 to 4.0 in.
L_o = 2.0 D to 3.0 D</td><td>3.56 - 10.16 cm</td><td>3</td><td rowspan="2">3 - 4</td></tr>
<tr><td>Lump (disturbed)</td><td>Cylindrical, recompacted</td><td>D = 1.4 to 4.0 in
L_o = 2.0 D to 3.0 D</td><td>3.56 - 10.16 cm</td><td>3</td></tr>
</table>

Legend:

D = diameter of cylindrical specimen

L_o = length or height of cylindrical specimen

G = largest grain diameter

sample is selected, preferably comprising a minimum of ten rock lump specimens each of which weighs at least 50 g, to give a total sample weight of 500 g. For in situ water content determination during sampling, storage and handling, care must be taken to retain the water content within 1% of its in situ value.

44. Tests for determining swelling pressure and strain must be conducted at the natural initial water content level; consequently, specimen preparation must be so conducted that the water content is retained within 1% of its in situ value.

45. Samples intended for uniaxial and triaxial compressive strength tests should be stored for no longer than 30 days, and then in such a manner that their natural water content is preserved. The prepared specimens should be conditioned for 5 to 6 days in an environment of 20°C ± 2°C with 50% ± 5% humidity prior to testing.

46. Rocks to be used in tests undertaken for determining the point load strength index are first divided into units, each of which is considered on the basis of a preliminary inspection, to have uniform strength. Samples containing sufficient material for the required

number of test specimens, are then selected from each unit. Core samples are preferred for reasons of accurate classification. Specimens should be tested in a state close to their natural water content. To obtain comparable index values, the samples should be conditioned as specified in para 45.

47. Special care must be taken when drilling and preparing specimens intended for determining ultrasonic constants, to minimize mechanical damage. Oven-dried specimens should be cooled and kept in a desiccator. Saturated specimens should remain submerged in water up to the time of testing.

48. Test specimens for direct shear test of a discontinuity, whether in block or in core, should be so selected, if possible, that the dimensions allow for adequate clearance for encapsulation without further trimming. The method for obtaining the specimens which contain the discontinuity to be tested, should avoid any disturbance of the natural water content. The dip and strike of the test horizon, together with other relevant geological characteristics, is recorded prior to sampling. Specimens which are not immediately encapsulated for testing, should be protected against any change in their natural water content. After binding together the rock pieces with wire or tape, they are either wrapped in plastic or coated with wax. Packaging should be appropriate to avoid any damage in transit. Fragile specimens require special treatment, such as packing in polyurethane foam.

PREPARATION OF CYLINDRICAL ROCK SPECIMENS

49. If blocks of the material are supplied, sample cores are obtained by using a diamond bit and drill press. A typical drilling set-up is shown in Fig 17. To prevent chipping and to provide good control of the drilling process, it is recommended that the following conditions be maintained:

a. drill speed, approximately 90 rpm,

b. drill feed, approximately 0.004 in./rev (0.1 m/rev).

50. The blocks of test material are usually squared on two opposing faces before being cored. Figure 18 shows a diamond saw used for this.

51. If the mechanical properties of the rock substance are to be tested in drill cores, samples free of obvious fractures or planes of weakness should be selected. If the objective is to determine shear strength of a fracture plane of weakness, samples containing these structural features should be selected. The samples selected are labelled and marked for cutting. Selected samples marked for cutting are shown in Fig 19 left; on the right side are specimens already cut to the desired length.

52. The core samples are cut by means of a diamond saw, as illustrated in Fig 20, where a 9.5 in. (24.13 cm) sample is being cut.

53. To ensure that the end surfaces of the specimens are normal to their axis and are also plane-parallel, they must be ground as in Fig 21. The frame, designed to hold the specimens in a vertical position, is able to take 12 specimens simultaneously.

54. The ends of specimens containing discontinuity planes should be ground individually. The two halves of the specimens are taped together, then clamped in a block and held in a vertical position. A typical set-up is shown in Fig 22.

55. Another method of grinding the end surfaces is shown in Fig 23. While the specimen is held firmly by the chuck of a lathe, its end surface is finished by a grinding wheel. The surface must be protected against the bite of the chuck by a layer of plastic sheeting around the specimen.

56. The quality of the circumferential surfaces of core specimens is usually acceptable for most rock types, and no further surface finishing is required. If the drilled surface contains abrupt irregularities however, or if strain gauges have to be applied to this surface, further finishing might be essential. This can be performed either by a roller lapping machine, as shown in Fig 24, or by surface grinding in a lathe as in Fig 25.

57. The sides of the specimens should be smooth and free of abrupt irregularities, with all

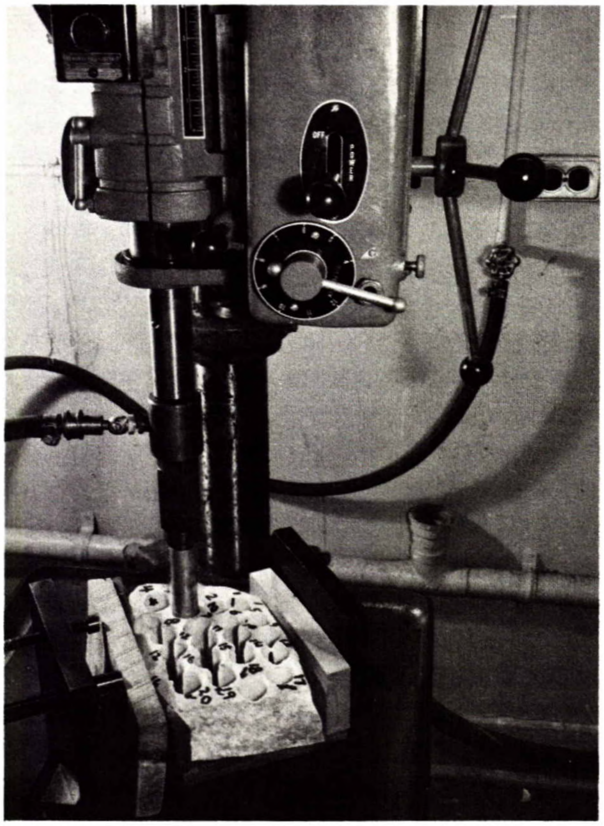


Fig 17 - Typical drilling set-up for laboratory coring.

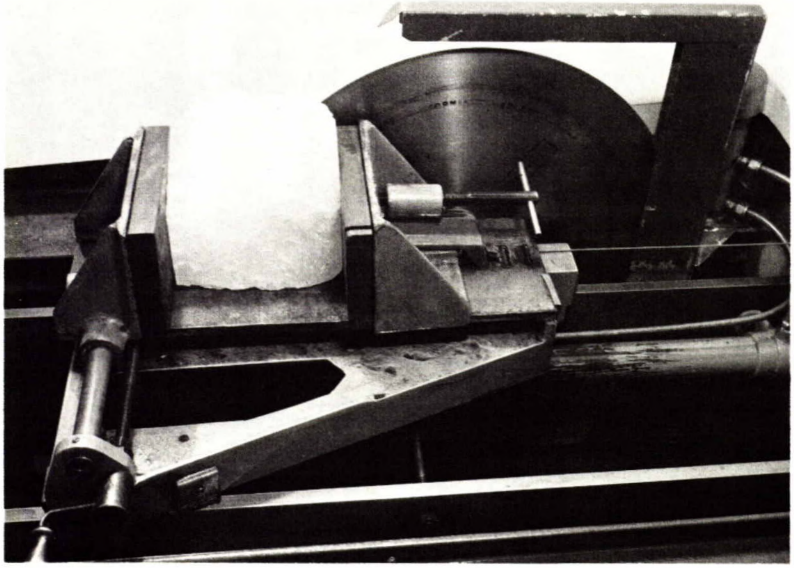


Fig 18 - Blocks of test material are usually squared on two opposing faces using diamond saw.

Fig 19 - Core samples marked up for cutting at left and specimens cut to the desired length at right.

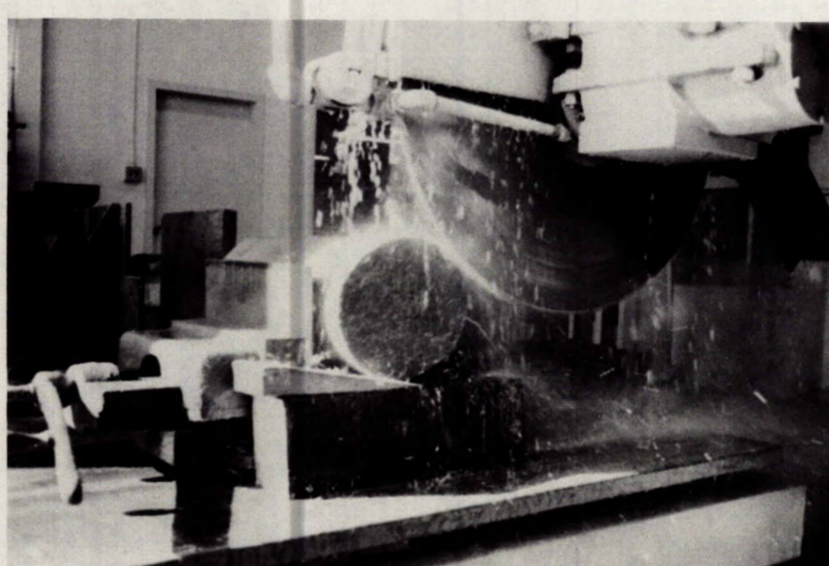


Fig 20 - Cutting core into lengths with a diamond saw.

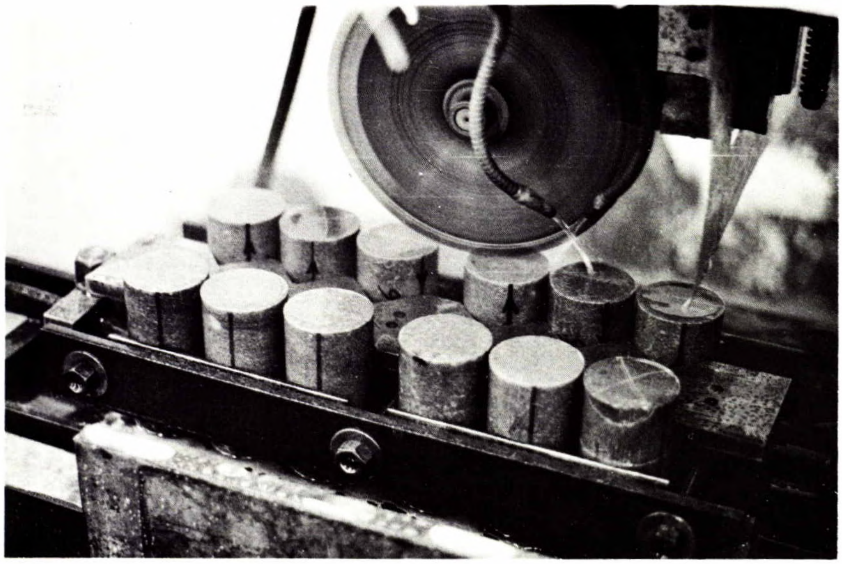


Fig 21 - Grinding end surfaces of solid core.

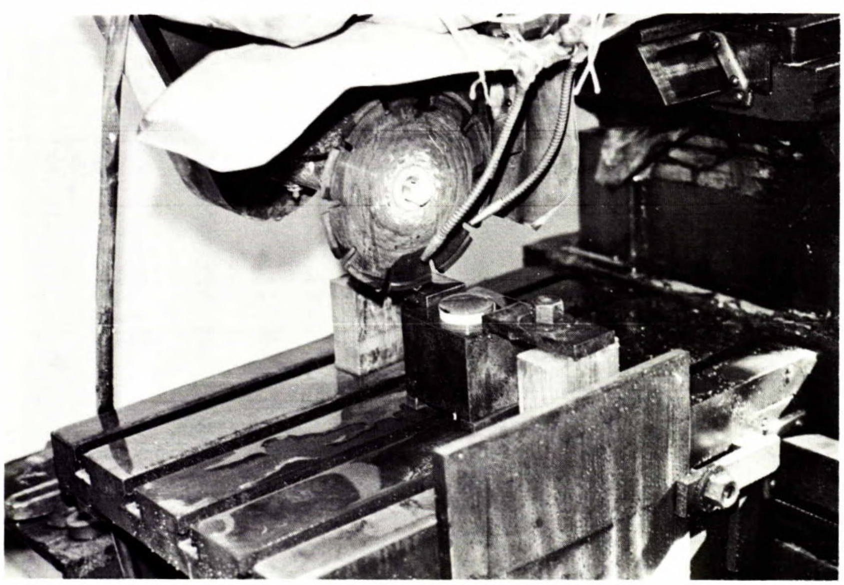


Fig 22 - Grinding end surfaces of fractured core specimen.

Fig 23 - Grinding end surfaces with lathe.

Fig 24 - Roller lapping machine for surface finishing.

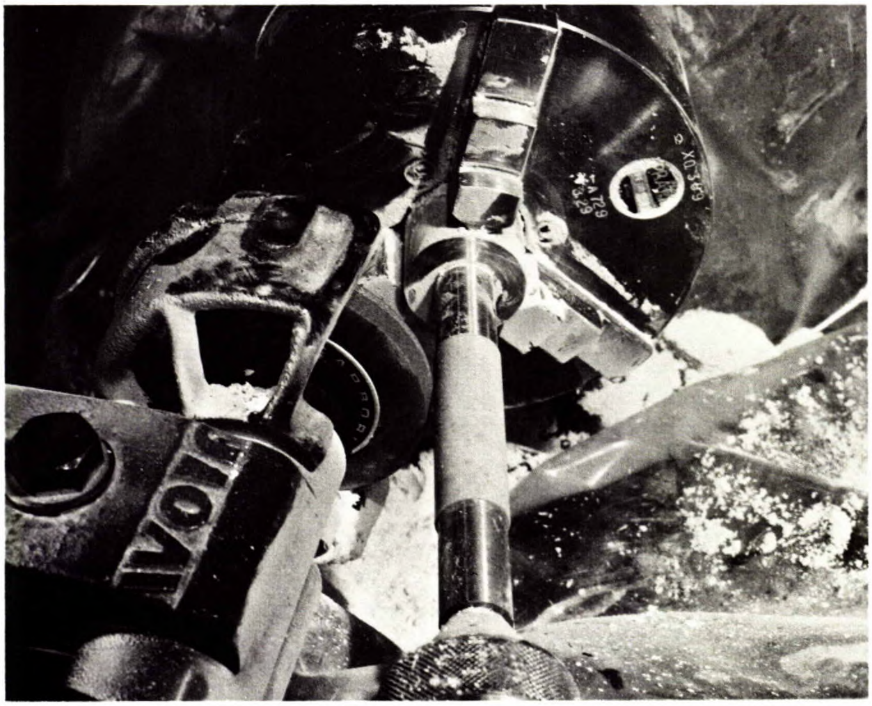


Fig 25 - Surface finishing in a lathe.

elements straight to within 0.005 in. (0.127 mm) over the full length. The ends should be parallel to each other within a tolerance of 0.001D, where D is the diameter of the specimen. The ends should be ground or lapped until flat to 0.001 in. (0.025 mm). They should be perpendicular to the axis of the specimen to within 0.25°, ie, to within approximately 0.01 in. in 2 in. (5 mm/m). These requirements are considered as having been met when five equally distributed measurements of the specimen height, taken by means of a dial comparator, agree to within 0.002 in. (0.05 mm) (6) (7).

PREPARATION OF SPECIMENS FOR DIRECT SHEAR TEST

58. During shear tests the two halves of the specimen, separated by the plane of discontinuity, are held together within the two frames of a shear box by grout material, cast around the specimen halves into moulds which correspond to those of the shear box itself. It is important that the planes of discontinuity to be tested are accurately aligned, and that a perfect match of the two specimen halves is assured along the shear surface. Several casting methods can be used, depending on the shape and size of the specimen and on that of the mould. One of these methods is detailed below.

59. If necessary, the sample is first trimmed by cutting off the excess rock material, as shown in Fig 26(a). For example, in cases of softer rocks and coal, a chain saw modified to accommodate a 12 in. (30.5 cm) circular rock blade, could be used for field cutting. For hard rocks a laboratory diamond saw is usually required.

60. Casting the first half of the specimen into the mould consists of the following steps:

a. the moulds are slightly greased to aid removal
b. the test specimen pieces are tied together by

wire loops

c. a mould is set level and checked with a spirit level

d. a sufficient amount of a very stiff grout material is placed to provide a firm bedding

e. the specimen is pushed into the grout bedding so that it is about in the centre of the mould and the eventual plane of shearing is roughly level at an elevation about 1 in. (2.54 cm) above the edge.

f. the wire loops are loosened, the upper half of the specimen is removed temporarily, and the lower half pressed down to its final position in the grout. At this position the projection of the discontinuity plane is no more than 0.25 to 0.35 in. (0.6 to 0.9 cm) above the edge of the mould. The plane must be horizontal.

g. the mould is completely filled with pourable grout, as shown in Fig 26(b).

61. After the grout has hardened, the second half of the specimen is cast into its mould. This procedure includes the following steps, Fig 26(c):

a. the upper half of the specimen is replaced, taking care that the shear surfaces are matched and the wire loops retied

b. a sufficient amount of fresh grout is poured into the levelled second mould to fill it, but allowing for the volume of the specimen half now to be cast

c. spacer blocks 0.5 to 0.7 in. (1.2 to 1.8 cm) in height, are placed around the edges of the mould; openings are left between these blocks through which excess grout can escape or additional grout added

d. the mould, containing the hardened grout together with a cast-in test specimen half, and the wired-on second specimen half is now inverted and carefully positioned above the mould containing the fresh grout

e. after cleaning up the excess grout which had overflown or adding additional grout to completely fill the second mould, if necessary, the moulds are left until the grout has hardened.

62. After hardening of the grout, the moulds are removed and the wire loops cut. At this stage the cast specimen is ready for placing in the shear box (Fig 26(d) and Fig 27).

63. The foregoing procedure assures satisfactory results when casting specimens. Figures 28 and 29 show two halves of a core specimen, as well as a block specimen after moulding.

64. The dimensions and the shape of the mould must correspond with those of the shear box. The moulds illustrated in Fig 30 are used with the portable shearing device shown in Fig 27 of Supplement 3-2. Note the slots and lines on the plexiglas sides that assist in the correct positioning of the specimen halves. Figure 31 shows the two halves of an NX size core specimen after moulding.

65. Several types of grout materials can be used:

a. KWIK-SET grout mixed with 27% water, which sets within 6 minutes and develops a compressive strength of 1000 psi (6.89 MPa) within 30 minutes. Because of its high cost at $5.00 per gallon, it is used only in case of field testing

b. a mixture of High Early cement and of KWIK-SET grout in a 1:1 ratio plus water, provides a grout material with a longer setting time. It can be used for both laboratory and field testing

c. a mixture of High Early cement and sand, in a 1:1 ratio plus water has a setting time which limits its use to laboratory testing only; it has however the lowest cost.

APPLICATION OF STRAIN GAUGES

66. When determining Poisson's ratio, both axial and circumferential strains are measured by strain gauges applied to the cylindrical specimen. If the elastic modulus is being determined, the axial strains are measured by means of a compressometer or by strain gauges.

67. Four strain gauges are mounted on the specimen used for determining Poisson's ratio. The two axial gauges are applied at midheight of the specimen, and diametrically opposed. The two circumferential gauges are similarly attached ie,

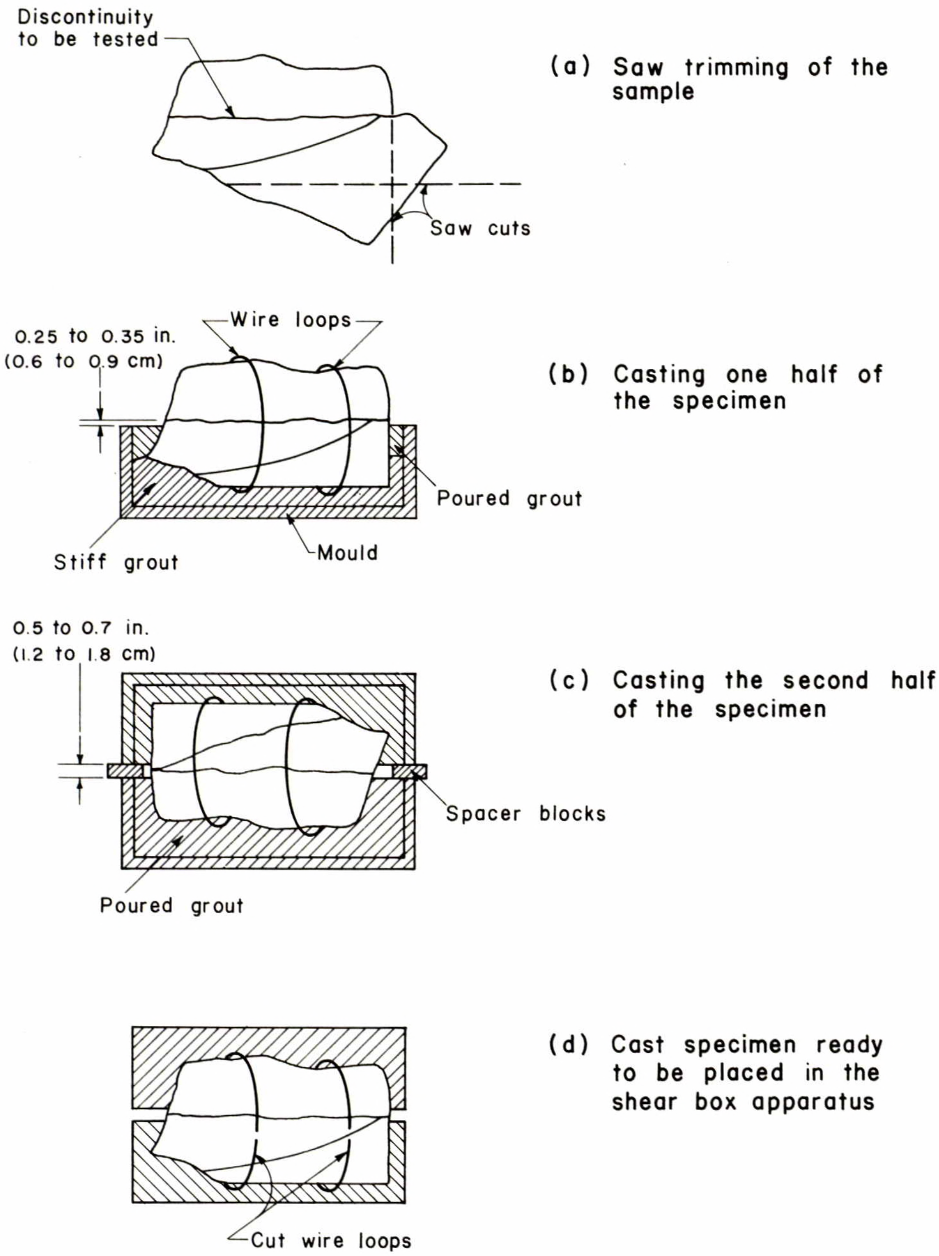


Fig 26 - Preparing specimen for direct shear test.

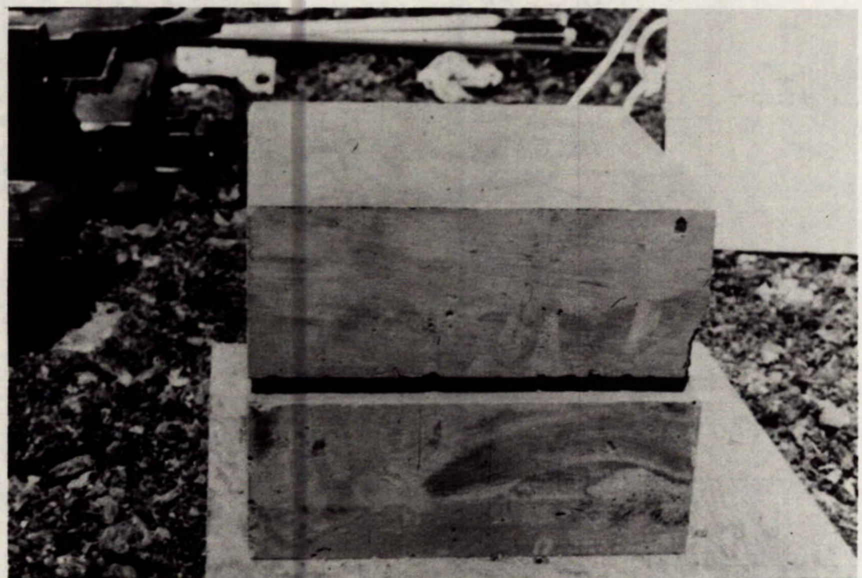


Fig 27 - Cast specimen ready to be placed in the shear box apparatus.

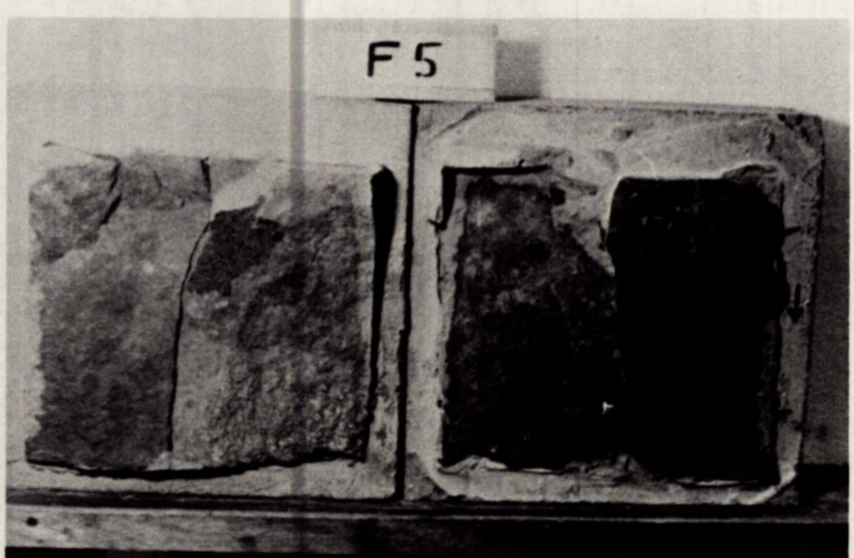


Fig 28 - Core specimen halves after casting.

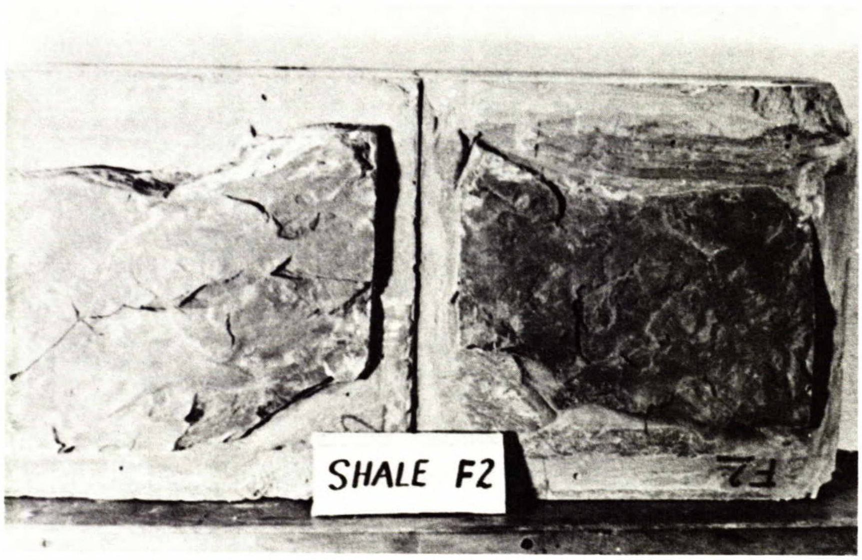


Fig 29 - Block specimen halves after casting.

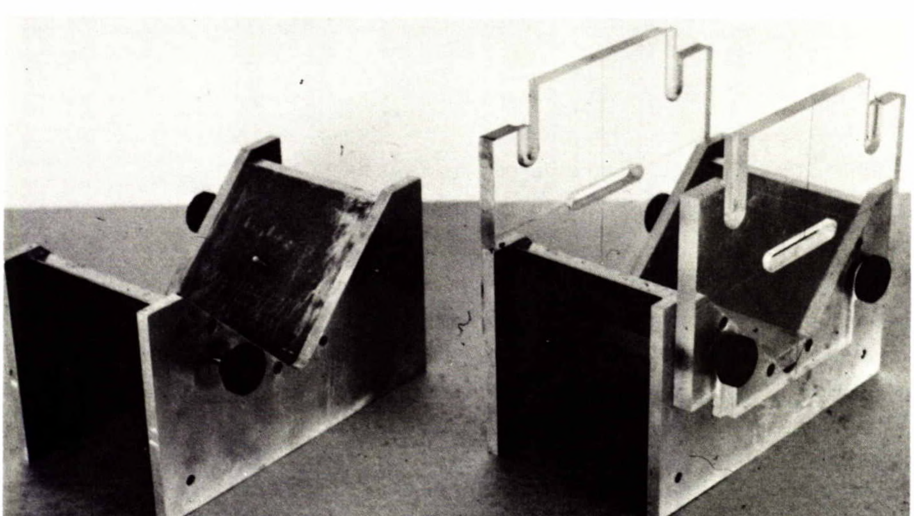


Fig 30 - Moulds used in conjunction with the portable shearing device for specimen casting.

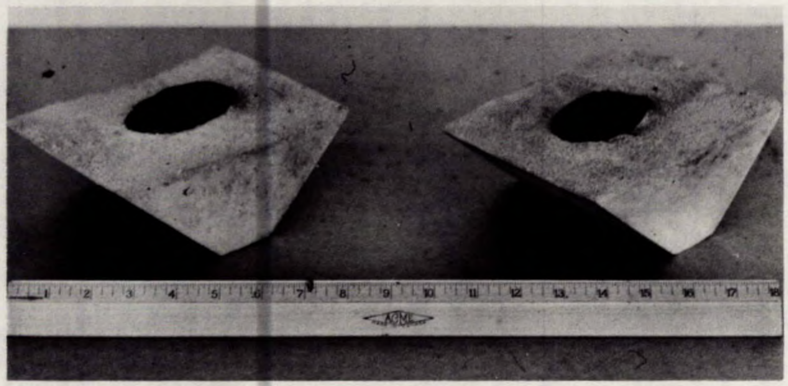


Fig 31 - Halves of an NX size core specimen after moulding.

are diametrically opposed and at a near midheight, but mounted at 90° to the axial gauges. It is necessary to apply gauges in pairs because of heterogeneity of the rocks, and the possibility of eccentric loading.

68. Since strain gauges are very sensitive to moisture, temperature, and mechanical disturbances, special precautions must be taken when applying them to rock specimens for consistent results. The following procedure is recommended:

a. Clean the specimens of all dust and grease and dry at room temperature for not less than two weeks.
b. Roughen the surface of the specimens with coarse emery paper or steel wool; a patch about 1/4 in. (6 mm) wider and longer than the gauge itself should be prepared for.
c. Remove all traces of oil and grease from the specimen with carbon tetrachloride, and dry for about 2 minutes.
d. Apply a small amount of cement to the gauge and to the prepared area of the rock specimen.
e. Press the gauge in place, taking care that it is properly aligned in horizontal and vertical directions; remove all air bubbles by rolling the thumb across a felt pad covering the gauge.
f. Place the specimen with all gauges attached in a special drying press. This press consists of two wooden blocks equipped with sponge rubber padded half-circle central holes, and two steel clamps.
g. Allow the cement to set for 24 hours with the specimen held firmly in the press; allow the specimen to dry for an additional 48 hours at room temperature.
h. Specimens which are not to be tested within 7 days should be waterproofed by coating with wax or Araldite and stored in sealed metal cans.
i. Before running the tests, the resistances should be checked with an ohmmeter to ensure that all gauges are functioning correctly. A minimum resistance of 100 megaohms between the gauge winding and the surface of the specimen is required for correct operation (8).

SOIL SPECIMEN PREPARATION FOR TRIAXIAL TEST

Undisturbed Specimens

69. In case of sensitive, varved or fissured clays, the best undisturbed specimens can be obtained from block samples. Very good specimens can also be obtained from cores taken with a 3 in. (7.6 cm) stationary piston sampler.

70. If the clay is so stiff that it is difficult to use such a sampler, samples may be taken

with an open thin-walled tube-sampler with a minimum diameter of 2 in. (5.1 cm). Consideration must however be given to the lower quality of such samples (9).

71. Actually no sample, whether from a handcut block or from boring, will provide specimens completely free of disturbances. The degree of disturbance and its effect on the test results, has to be assessed for each soil type and condition. Sensitivity to disturbance is most marked in normally consolidated clays, particularly in those having a low plasticity index. The Canadian Leda clay is one of the best known clays of high sensitivity; it requires special sampling and laboratory techniques (10).

72. In case of soils of low or moderate sensitivity, the simplest method of preparing specimens for triaxial testing is to use a thin-walled cutter. The cutter consists of a polished brass tube, of 1.5 in. (37 mm) internal diameter, 0.03 in. (0.76 mm) wall thickness, and 6 in. (15 cm) length. The face of the sample is trimmed flat and the sharpened and lubricated cutter is forced into it. Next, the cutter is laid flat and the soil pushed out with a loose fitting wooden cylinder, until about 0.5 in. (1.3 cm) of soil projects at the cutter end. Because this projecting material is likely to be disturbed, it is trimmed square. Ejection from the cutter is then continued until the length of soil material ejected equals the desired length of the specimen. The specimen, usually 3 in. (7.6 cm) in length, is then trimmed off.

73. Since the material is protected by the cutter until it is ejected, the drying effect is minimized. The foregoing procedure can be used for clays, and also for sandy strata with little cohesion.

74. In highly sensitive clays it is preferable to obtain the specimen by means of a wire saw trimming. While being trimmed the soil block is held between two platens which can be rotated.

75. Before the specimen is placed in the test cell, its weight is established to the nearest 0.1 g. The length and diameter of the specimen are also measured. If a cutter is used, its internal diameter can be taken as that of the specimen.

Compacted Specimens

76. Specimens of 4 in. (10.2 cm) diameter are usually prepared to facilitate correlation with the standard compaction test, and also to enable a wide range of particle sizes to be included in the test specimen.

77. For specimen compaction, a three-part, split, 8 in. (20.3 cm) long mould is used, which fits the base and collar of the standard compaction test apparatus. The specimen is prepared by placing and compacting six layers of material having the desired water content. Particles up to 3/8 in. (9.5 mm) in size may be included in the specimen (11).

78. The above gives only brief descriptions of well developed techniques used in the field of soil mechanics. Full details are outside the scope of this supplement, because they more properly belong to the special field of soil mechanics and described in the given references. This is especially true for triaxial testing of cohesionless soils, which includes highly specialized preparation techniques based on special features(12).

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