November 12, 1959

W. W. Hansen Laboratories of Physics
Stanford University
Stanford, California

Attention: Dr. Frank W. Atchley

Gentlemen:

Ten copies of our report, "Preliminary Site Investigation, Proposed Target and Research Area--Linear Electron Accelerator, Stanford, California, For Stanford University," are herewith submitted.

During the progress of our work, our findings were discussed with Dr. Atchley. Our studies indicate that the site could be developed for its planned ultimate usage.

The above investigation was performed under the terms of your Purchase Order No. US 68815, dated October 19, 1959.

Yours very truly,

DAMES & MOORE

William W. Moore

Charles L. Nichols

WMM-CLN-JDM AT
This report presents the results of our preliminary investigation at the subject site. The site is approximately two miles south of the Stanford University Campus, south of the intersection of Page Mill Road and Junipero Serra Boulevard, as indicated on the Plot Plan, Plate 1.

PROPOSED DEVELOPMENT

This work relates to the proposed target and research area at the east end of the proposed two-mile long linear electron accelerator tunnel. The locations of the two proposed alternate alignments of the linear accelerator and main target buildings are indicated on the Plot Plan.

Ultimate development plans for the target and research area have not been established yet. Tentative plans indicate that a proposed target structure will occupy a maximum area of 500 by 400 feet at the end of the accelerator. This building may involve extremely heavy foundation loads on the probable order of 15 to 20 kips per square foot, depending on the location and type of shielding protection selected. Auxiliary facilities located in the target research area are expected to impose light to moderately heavy foundation loading. Certain installations, such as the deflection magnet housing structure, will involve heavy individual concentrated loadings.
Earthwork and site preparation will depend on final location and elevation of facilities. Under the tentative south scheme, the target building floor elevation would be approximately 150. Cuts 50 feet deep and areal fills 25 feet deep may be involved in site development. As presently proposed, the north target building floor elevation would be approximately 135. This alignment scheme would involve less grading. Under either scheme, shielding of the electron tube between the tunnel portal and the target structure may require a minimum 35-foot deep earth cover.

SCOPE OF INVESTIGATION

The purpose of our investigation was to provide a soils and foundation feasibility study of the subject area for its planned usage. The scope of the investigation covered the following:

1. General site soil conditions.
2. Suitability of the alternate target building sites for extremely heavy concrete structures.
3. Suitability of adjacent areas for support of the more normal type structures.
4. Discussion of the type of site preparation which would be required for structures near existing grade, or for the placement of 20 to 25 feet of fill.
5. Feasibility of using tunnel muck as fill to support structures.
6. Comments on slope stability.

A description of field and laboratory tests, and log of test borings are included in Appendix A.
SITE CONDITIONS

The area investigated is roughly contained within a 2000-foot sided square, bounded on the north and west by Junipero Serra Boulevard and Page Mill Road. The site is hilly, as indicated by the contours on the Plot Plan. It is mostly grass covered, with some trees, and is presently used for dairy farming.

Borings in the proposed target building areas disclosed soft weathered sandstone at shallow depth. These deposits are typical of the Tertiary Searsville or Los Trancos formations which underlie the major portion of the site east of Page Mill Road. In general, the sandstones encountered were fine grained, in some cases approaching a siltstone classification. The upper zone, varying in depth from several to 30 feet, exhibited weathered, oxidized characteristics (light brown color, weak cementation, easy drilling). All borings were drilled to refusal, where the sandstone becomes less weathered, changes to gray in color and possesses moderate to strong cementation. On the hill slopes above approximately Elevation 150, the depth of surface soil overlying the weathered sandstone did not exceed two to three feet.

On the balance of the site, below Elevation approximately 150, recent alluvial deposits overlie older Tertiary sandstone formations. The area north of the proposed accelerator alignments and between Matadero and Purisima Creeks is presently a generally level plain formed by alluvial deposits up to 25 feet in depth. The two afore-mentioned small creeks, originating in the hills to the south, pass through the alluvium margins on the northwestern and eastern sides. The creeks have steep sides and are about 10 feet deep. Sandstone outcrops are exposed at several locations along the creeks.
The alluvial deposits vary from silty clays near the surface to sand or silt-clay-gravel mixtures. The upper clayey soils are moderately expansive when saturated under small confining pressures. All alluvial soils encountered exhibit slight to moderate compressibility characteristics.

Borings A and N encountered fine grained basalt at 16 and 9 feet, respectively. At Boring A, the presence of Tertiary basalt underlying alluvium confirmed earlier geological data. At Boring N, the basalt did not conform with supplied geological information. A sandstone outcrop in the adjacent creek indicates that the basalt encountered in this area is either part of a marginal flow or possibly a large stray boulder.

**DISCUSSION AND RECOMMENDATIONS**

From our study of the subsurface conditions, we believe that the site would be satisfactory for the planned usage. The tentative south scheme would have less alluvium below the proposed target building and electron beam alignment, and thus would furnish better support than would the north scheme.

**TARGET BUILDING AREA:**

The weathered yellow-brown fine-grain sandstones would be suitable for supporting heavy loads of 15 kips or so per square foot, provided suitable design provisions are made for foundation depth, drainage, and vertical deflection under load. **Further field investigations and tests should be made prior to final design for the very heavy loads contemplated. Vertical deflection of the sandstone under load should be considered as it may possibly influence desired construction sequence, such as connection of floors to foundations, etc.**
In the proposed south target building area, sandstone is close to the surface and will require excavation to considerable depth over most of the area. The weathered sandstone, although firm, is weakly cemented and should not be difficult to excavate.

In the proposed north alignment target building area, the sandstone is deeper below the surface. In order to support very heavy loads, this would either require taking some foundations fairly deep or moving the building site further into the hillside.

If there are to be extremely heavily loaded floors that are not supported on the sandstone, special consideration would be required for floor support. This could include removing the upper soil and replacing with well compacted select fill, or possibly separating the floor slab from the foundations in order to permit differential settling without severe cracking of the floor slab.

It would possibly be desirable to carry some extremely heavy loads down through the weathered sandstone to the less weathered gray sandstone. Since our borings were not planned to penetrate into the harder gray sandstone, where they met refusal, it would be desirable to obtain some cores of this material in order to determine its character at greater depth.

Extensive volcanic outcrops in the hillside southeast of the proposed north alignment target building indicate the presence of a fault or contact zone. Cut slopes associated with development of the target building and adjacent areas may produce adverse stability and seepage problems. These factors should be considered in subsequent site investigations if the north scheme is adopted.
ACCELERATOR ALIGNMENT:

Between the tunnel portal and the target building, we understand that the electron beam housing will probably be under about 35 feet of shielding fill. If the south scheme is used, elevation of the beam housing would be about 155, and most of this distance is expected to be in rock cut. Consequently, the shielding fill would not be expected to cause much settlement along most of the distance. However, near Borings A and C the beam structure would not be in rock and the deflection created by the 35 feet of shielding fill should be considered in design.

If the north alignment scheme is followed, the electron beam housing structure is expected to be at approximately Elevation 135. Various depths of underlying alluvium combined with 35 feet of shielding fill will cause some settlement which must be considered in design. Two inches or more of settlement is possible. If further studies show that potential settlement of the electron beam housing is more than can be tolerated following construction, one of several precautions could then be taken, including:

1. Excavate existing soil and replace with a well compacted select fill.
2. Place the shielding fill over the structure as early as possible in order to cause most of the settlement to occur prior to operation.
3. Support the beam housing structure on piles or caissons.

In the electron beam switchyard area, deflection magnets may impose heavy concentrated loads. Support for these would require additional study.
If loads are very heavy and sensitive, they could be supported on the sandstone either by spread foundations, piles or caissons.

**ADJOINING RESEARCH AREA:**

The adjoining area can be suitably developed for normal type structures imposing moderate loads. Primarily under consideration is the alluvial plain between the two creeks. However, other adjoining areas could also be suitably developed.

If the north alignment is followed, the alluvial plain is expected to be filled to approximately Elevation 130, which would require a small amount of fill. The upper soil is adobe-like and subject to considerable volume change with changes in moisture content. This factor must be considered, especially where little or no fill is to be placed. Some of this upper soil may require removal or recompaction. Otherwise, the natural soils are moderately firm and would be suitable for moderate foundation loading.

If the south alignment is used, we understand it is considered desirable to fill the adjacent areas to approximately Elevation 150, using tunnel excavation as fill material. If the existing surface is properly prepared and suitable fill is properly placed and compacted under engineering control, the fill could support normal buildings satisfactorily.

Geological data and tunnel borings made thus far indicate that sandstone, clay stone and basalt exist along the tunnel alignment. We expect the sandstone and basalt to be suitable for good quality fill. The clay stone and other clayey material could be used but would be more difficult and expensive to properly condition and compact into place. We suggest that its use be confined to noncritical areas, if possible.
SLOPE STABILITY:

The stability of deep excavation slopes in natural materials will be dependent largely upon formation structure, fault and seepage zones, and other geological considerations. From the data presently available, we would expect that cut faces in sandstone formations may be excavated to slopes of approximately one vertical to one horizontal. However, the factors indicated above could vary this considerably in local areas. Benching and slope drainage precautions may be required in deep cuts.

If fill slopes are placed under proper engineering control to obtain adequate compaction, we estimate that they would be stable at approximately one and one-half horizontal to one vertical.

The following Plate and Appendix are attached and complete this report:

Plate 1  - Plot Plan

Appendix A - Field Explorations and Laboratory Testing

Respectfully submitted,

DAMES & MOORE

William W. Moore
Charles L. Nichols
PLOT PLAN

NOTE:
CONTOUR ELEVATIONS
REFER TO U.S.C. & S.S. DATUM
FIELD EXPLORATIONS AND LABORATORY TESTING

FIELD EXPLORATIONS:

Subsurface conditions in the area of the proposed development were explored by drilling 13 test borings at the locations indicated on the Plot Plan. The borings were drilled to depths of 9 to 31 feet with bucket-type drilling equipment. The borings were drilled under the supervision of our Engineer. The subsoils encountered were classified by visual and textural examination and a limited number of representative undisturbed samples were extracted for laboratory testing. The boring logs are presented graphically on Plates A1A through A1F. The method of classifying soil types is indicated on Plate A2. The soil sampler used to extract undisturbed samples is illustrated on Plate A4.

The depths at which seepage water was indicated in the test borings is shown on the boring logs. Seepage was generally encountered in the lower gravelly deposits of the borings located in the alluvial plain area. As an indication of the quantity of seepage flow and stabilized ground water table elevations, several test borings were temporarily left open to observe water levels. From our observations, it is concluded that at the time of our exploration the ground water table across the alluvial plain varied from approximately Elevation 115 on the west to Elevation 108 on the east.

All of the borings were drilled to refusal without the use of casing. Some minor caving occurred in the gravelly alluvial soils at the seepage zones but in no case did the caving prevent advancing of the boring.
LABORATORY TESTING:

In order to determine the general characteristics of the subsoils, a limited program of laboratory testing was performed on representative samples.

Direct Shear Tests: The shear strengths of representative samples were determined by direct shear tests; the method for performing these tests is described on Plate A5. In general, the soils were tested at field moisture conditions under confining pressures equal to the weight of the existing overburden. Certain samples of the topsoils and alluvial deposits were tested at artificially increased moisture content to determine their probable strength with the infiltration of surface or subsurface water. Moisture and density determinations of sheared samples were used to correlate direct shear and consolidation test results. The results of direct shear tests and moisture-density determinations are presented to the left of the boring logs. The method of presentation is described by the Key to Test Data on Plate A2.

Consolidation Tests: To determine the compressibility of the upper alluvial soils, two representative samples were subjected to consolidation (confined compression) tests. The results of these tests are presented on Plate A3. The method used in performing the consolidation tests is described on Plate A6.

The following Plates are attached and complete this Appendix:

Plates A LA through A LF - Log of Borings (Borings A through N)
Plate A2 - Soil Classification Chart and Key to Test Data
Plate A3 - Consolidation Test Data
Plate A4  - Soil Sampler, Type D
Plate A5  - Method of Performing Direct Shear and Friction Tests
Plate A6  - Method of Performing Consolidation Tests
LOG OF BORINGS
BORING D
DRILLED 10-21-59

SHEARING STRENGTH IN LBS./SQ. FT.

ELEVATION 189.4'
- DARK BROWN CLAY WITH ROOTS (CL)
- LIGHT YELLOWISH-BROWN FINE SANDY SILT
- WITH WEATHERED SILTSTONE FRAGMENTS (SW)
- LIGHT WHITE-YELLOW SANDSTONE
  (WEATHERED, HARD, CEMENTED)
- (GRADING LIGHT YELLOWISH-BROWN,
  SOFT, LIGHTLY CEMENTED)
- (GRADING OCCASIONAL CLAY SEAMS)
- (GRADING LIGHT GRAY & BROWN)
- (GRADING SOME HARD CALCAREOUS LENSES
  WITH OCCASIONAL SHELL FRAGMENTS)
- (GRADING LIGHT BROWN)
- (INCREASE IN WHOLE SHELLS)
- (GRADING MODERATELY CEMENTED)
- (GRADING TO FINE SANDSTONE WITH MANY
  SMALL SHELLS)
- (GRADING STRONGLY CEMENTED)

BORING E
DRILLED 10-24-59

ELEVATION 152.2'
- DARK BROWNISH-BLACK CLAY WITH ROOTS (CL)
- LIGHT YELLOWISH-BROWN FINE SANDSTONE
  (WEATHERED, SOFT, LIGHTLY CEMENTED)
- (GRADING LIGHT GRAY & BROWN;
  MODERATELY CEMENTED)
- (GRADING LIGHT BROWN)
- (GRADING LIGHTLY CEMENTED)
- (GRADING LIGHT GRAYISH-BROWN WITH BROWN
  VEINS & OCCASIONAL SHELLS)
- (GRADING TO GRAY NON WEATHERED,
  HARD, STRONGLY CEMENTED)

LOG OF BORINGS
### BORING F
**Drilled 10-22-59**

<table>
<thead>
<tr>
<th>Elevation</th>
<th>Shearing Strength (lbs./sq. ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>140</td>
<td></td>
</tr>
<tr>
<td>135</td>
<td></td>
</tr>
<tr>
<td>130</td>
<td>22.9% - 103</td>
</tr>
<tr>
<td>125</td>
<td></td>
</tr>
<tr>
<td>120</td>
<td></td>
</tr>
<tr>
<td>115</td>
<td>20.4% - 106</td>
</tr>
<tr>
<td>110</td>
<td></td>
</tr>
<tr>
<td>105</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td></td>
</tr>
<tr>
<td>95</td>
<td></td>
</tr>
</tbody>
</table>

- **Dark Brownish-Black Silty & Sandy Clay with some small gravel (CL)**
- **Brown Fine Silty Sand with small amount of binder & small gravel (SM)**
- **Brown Clay (CL)**
- **Brown Clay (CL)**
- **Grading Light Brown**
- **Grading Small Gravel; Moist**
- **Light Brownish-Gray Clayey Fine Sand with some small gravel (SG-GC)**
- **Grading Much Large Gravel & Cobble, Seepage Water**
- **Grading Less Gravel**
- **Gray Sandstone (weathered, soft, lightly cemented)**
- **Grading To Non Weathered, Hard, Strongly Cemented**

### BORING G
**Drilled 10-21-59 - 10-22-59**

<table>
<thead>
<tr>
<th>Elevation</th>
<th>Shearing Strength (lbs./sq. ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>140</td>
<td></td>
</tr>
<tr>
<td>135</td>
<td></td>
</tr>
<tr>
<td>130</td>
<td></td>
</tr>
<tr>
<td>125</td>
<td>1050 - 16.2% - 112 - 9.9%</td>
</tr>
<tr>
<td>120</td>
<td></td>
</tr>
<tr>
<td>115</td>
<td>25.8% - 99</td>
</tr>
<tr>
<td>110</td>
<td></td>
</tr>
<tr>
<td>105</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td></td>
</tr>
<tr>
<td>95</td>
<td></td>
</tr>
</tbody>
</table>

- **Dark Brown Sand-Clay Fine to Medium Gravel Mixture (GC)**
- **Brown & Yellowish-Brown Clayey Silt (ML)**
- **Brown Clayey Fine Sand with some gravel (SC)**
- **Grading Dryish-Gray**
- **Grading To Gray Fine Sandstone, Non Weathered, Mod., Hard**
- **Grading Moderately Cemented**
- **Grading Strongly Cemented**

### LOG OF BORINGS
LOG OF BORINGS

BORING H
DRILLED 10-27-59

BORING I
DRILLED 10-27-59

BORING J
DRILLED 10-22-59

ELEVATION 132.2'
BROWN FINE SANDY SILT WITH SLIGHT CLAY BINDER (SM)
DARK GRAYISH-BROWN SILTY CLAY WITH OCCASIONAL SMALL GRAVEL (CL)
(ROUTES TO 28' DEPTH)
(Grading Brown with occasional pockets of gray cemented silty sand)
GRAY & BROWN SAND-CLAY-GRAVEL MIXTURE (GC)
(FINE TO COARSE GRAVEL AND SMALL COBBLES)
(Grading cobbles to 4" DIAM.)
LIGHT GREENISH-BROWN CLAYEY SILT WITH OCCASIONAL SMALL GRAVEL (ML)
(Grading lenses of black clayey silt)
(GRADING VERY MOIST)
GREENISH-BROWN SANDSTONE (WEATHERED, MODERATELY HARD, MODERATELY CEMENTED)
(Grading gray, non weathered, hard, strongly cemented)

ELEVATION 155.7'
DARK BROWNISH-BLACK SILTY CLAY WITH OCCASIONAL SMALL GRAVEL (CL)
(Grading light brownish-gray & grayish-brown fine sandy clays)
LIGHT YELLOWISH-BROWN SILTY FINE SAND WITH LARGE GRAVEL TO COBBLES (SM)
(Grading slight cementation)
LIGHT YELLOWISH-BROWN & GRAY SANDSTONE (WEATHERED, MODERATELY HARD,
MODERATELY CEMENTED)
(Grading light gray to white)
(Grading strongly cemented)

ELEVATION 121.0'
BROWN SANDY CLAY WITH FINE GRAVEL AND ROOTS (SC)
BROWN SILTY CLAY (CL)
(ROUTES TO 2' DEPTH)
(Grading fine gravel)
(Grading light brown; no gravel)
(Grading occasional fine gravel)
LIGHT BROWN CLAY-GRAVEL MIXTURE (GM)
(Grading much gravel & cobbles) (strong in-flow of water)
LIGHT GREENISH-BROWN SANDSTONE (WEATHERED, SOFT, LIGHTLY CEMENTED)
(Grading gray; non weathered, mod. hard, mod. cemented)
(Grading strongly cemented)
BORING K
DRILLED 10-23-59

LOG OF BORINGS

BORING L
DRILLED 10-24-59

SHEARING STRENGTH IN LBS./SF.FT.
BORING M
DRILLED 10-27-59

ELEVATION 154.1'
BROWN SANDY & SILTY CLAY WITH OCCASIONAL SMALL GRAVEL &
ROOTS (CL)
BROWN CLAYET SILT (ML)
(Grading less clayey)
LIGHT TELLOWISH-BROWN FINE SANDY SILT (SM)
(Some partly cemented fragments)
(Grading Brown Silt, Fine to Coarse Sand, with occasional
Fine Gravel)
LIGHT BROWN & BROWN SAND-SILT-GRVEL MIXTURE (GM)
LIGHT GREENISH-GRAY & YELLOW FINE SANDY SILT WITH OCCASIONAL
FINE TO MEDIUM GRAVEL (SM)
LIGHT GREENISH-GRAY & TELLOWISH-BROWN SANDSTONE
(Weathered, Soft, Lightly Cemented)

(Grading Greenish-Gray)
(Grading to Clay, Non Weathered, Moderately Hard, Moderately
Cemented)

BORING N
DRILLED 10-27-59

ELEVATION 134.0'
BROWN SLIGHTLY SILTY CLAY WITH ROOTS (CL)
LIGHT BROWN FINE SANDY SILT WITH SMALL GRAVEL (ML)
(Grading Some Large Gravel to Small Cobbles)
(Grading Reddish-Brown)
REDDISH-BROWN SAND-SILT-FINE TO COARSE GRAVEL MIXTURE (GM)
REDDISH-BROWN SAND-CLAY-FINE TO COARSE GRAVEL MIXTURE (GC)
(Grading Cobbles & Small Cobblestones)
GRAY BASALT (Fine Grained)

LOG OF BORINGS
### Soil Classification Chart

<table>
<thead>
<tr>
<th>MAJOR DIVISIONS</th>
<th>LETTER</th>
<th>SYMBOL</th>
<th>NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silts and Clays</td>
<td>LL ≤ 50</td>
<td>CM</td>
<td>Silty gravels, gravel-sand-silt mixtures</td>
</tr>
<tr>
<td></td>
<td>CM</td>
<td>GC</td>
<td>Clayey gravels, gravel-sand-clay mixtures</td>
</tr>
<tr>
<td></td>
<td>SP</td>
<td>GF</td>
<td>Poorly-graded sands or gravelly sands, little or no fines</td>
</tr>
<tr>
<td></td>
<td>SW</td>
<td>SW</td>
<td>Well-graded sands or gravelly sands, little or no fines</td>
</tr>
<tr>
<td></td>
<td>SM</td>
<td>SM</td>
<td>Silty sands, sand-silt mixtures</td>
</tr>
<tr>
<td></td>
<td>SC</td>
<td>SC</td>
<td>Clayey sands, sand-clay mixtures</td>
</tr>
<tr>
<td></td>
<td>ML</td>
<td>ML</td>
<td>Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity</td>
</tr>
<tr>
<td></td>
<td>CL</td>
<td>CL</td>
<td>Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays</td>
</tr>
<tr>
<td></td>
<td>OL</td>
<td>OL</td>
<td>Organic silts and organic silt-clays of low plasticity</td>
</tr>
<tr>
<td></td>
<td>MH</td>
<td>MH</td>
<td>Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts</td>
</tr>
<tr>
<td></td>
<td>CH</td>
<td>CH</td>
<td>Inorganic clays of high plasticity, fat clays</td>
</tr>
<tr>
<td></td>
<td>DH</td>
<td>DH</td>
<td>Organic clays of medium to high plasticity, organic silts</td>
</tr>
<tr>
<td></td>
<td>Pt</td>
<td>Pt</td>
<td>Peat and other highly organic soils</td>
</tr>
</tbody>
</table>

### Plasticity Chart

**SOIL CLASSIFICATION CHART**

(UNIFIED SOIL CLASSIFICATION SYSTEM)

#### Tests at Field Moisture
- **Test Saturated Pressure in Pounds per square foot**
- **Per cent Field Moisture expressed as a percentage of the dry weight of soil**

#### Tests at Artificially Changed Moisture
- **Dry Density expressed in Pounds per cubic foot**
- **Per cent moisture when tested expressed as a percentage of the dry weight of soil**

**DIRECT SHEAR - STRAIN CONTROL**

- Yield point shearing strength in lbs per sq ft

**KEY TO TEST DATA**

![Diagram of soil classification chart with details on major divisions, letter symbols, and names of soil types.](Plate A2.png)
CONSOLIDATION TEST DATA
SOIL SAMPLER TYPE D
FOR SOILS EASY TO RETAIN IN SAMPLER

DRIVING OR PUSHING MECHANISM

WATER OUTLETS

CHECK VALVE

NEOPRENE SEAT

HEAD

NOTCHES FOR ENGAGING FISHING TOOL

HEAD EXTENSION (OPTIONAL)

SPACE TO RECEIVE DISTURBED SOIL

BARREL

CORE-RETAINER RINGS
(2 1/8" O.D. BY 1" LONG)

ALTERNATE ATTACHMENTS

BARREL

BARREL COUPLING

SAMPLING TUBE COUPLING

SPLIT FERRULE

LOCKING RING

THIN-WALLED SAMPLING TUBE
(6" AND 12" TUBES INTERCHANGEABLE)

NOTE:
SAMPLE IS EXTRUDED INTO CORE RETAINER RINGS IMMEDIATELY UPON COMPLETION OF SAMPLING OPERATION.

PLATE A4
METHOD OF PERFORMING DIRECT SHEAR AND FRICTION TESTS

Direct shear tests are performed to determine the shearing strengths of soils. Friction tests are performed to determine the frictional resistances between soils and various other materials such as wood, steel, or concrete. The tests are performed in the laboratory to simulate anticipated field conditions.

Each sample is tested within three brass rings, two and one-half inches in diameter and one inch in length. Undisturbed samples of in-place soils are tested in rings taken from the sampling tool in which the samples were obtained. Loose samples of soils to be used in constructing earth fills are compacted in rings to predetermined conditions and tested.

Direct Shear Tests

A three-inch length of the sample is tested in direct double shear. A constant pressure, appropriate to the conditions of the problem for which the test is being performed, is applied normal to the ends of the sample through porous stones. A shearing failure of the sample is caused by moving the center ring in a direction perpendicular to the axis of the sample. Transverse movement of the outer rings is prevented.

The shearing failure may be accomplished by applying to the center ring either a constant rate of load, a constant rate of deflection, or increments of load or deflection. In each case, the shearing load and the deflections in both the axial and transverse directions are recorded and plotted. The shearing strength of the soil is determined from the resulting load-deflection curves.

Friction Tests

In order to determine the frictional resistance between soil and the surfaces of various materials, the center ring of soil in the direct shear test is replaced by a disk of the material to be tested. The test is then performed in the same manner as the direct shear test by forcing the disk of material from the soil surfaces.
Consolidation tests are performed to evaluate the volume changes of soils subjected to increased loads. Time-consolidation and pressure-consolidation curves may be plotted from the data obtained in the tests. Engineering analyses based on these curves permit estimates to be made of the probable magnitude and rate of settlement of the tested soils under applied loads.

Each sample is tested within a brass ring two and one-half inches in diameter and one inch in length. Undisturbed samples of in-place soils are tested in rings taken from the sampling tool in which the samples were obtained. Loose samples of soils to be used in constructing earth fills are compacted in rings to predetermined conditions and tested.

In testing, the sample is rigidly confined laterally by the brass ring. Axial loads are transmitted to the ends of the sample by porous disks. The disks allow drainage of the loaded sample. The axial compression or expansion of the sample is measured by a micrometer dial indicator at appropriate time intervals after each load increment is applied. Each load is ordinarily twice the preceding load. The increments are selected to obtain consolidation data representing the field loading conditions for which the test is being performed. Each load increment is allowed to act over an interval of time dependent on the type and extent of the soil in the field.

Soils saturated in the field are tested submerged in water. The effect of increased moisture content on partially saturated soils is determined by adding water to the sample during the test.