GCTS is committed to designing accurate testing systems by integrating innovative software engineering with advanced hardware. GCTS systems perform at the highest levels of reliability, providing efficient systems that satisfy customer needs and expectations.

GCTS
TESTING SYSTEMS

SPAX-1000 & 2000
Poly-Axial Test Systems

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21

- Tests cubical specimens 75 x 75 mm by 150 mm height
- Capable of applying the following maximum stresses depending on the system:

System	Max. Minor Stress	Max. Major Stress
SPAX-1000	1 MPa	1 MPa
SPAX-2000	2 MPa	5 MPa

- Independent stress or strain closed-loop digital servo control of each one of the three axes
- Front and back-hinged doors swing open for easy specimen access
- Internal load cells are rigidly attached to upper and both side loading platens
- Especially well suited for K_o-consolidation testing
- “Turn-key” systems
- Systems also manufactured to customer specifications
- Unsaturated soils triaxial testing

DESCRIPTION

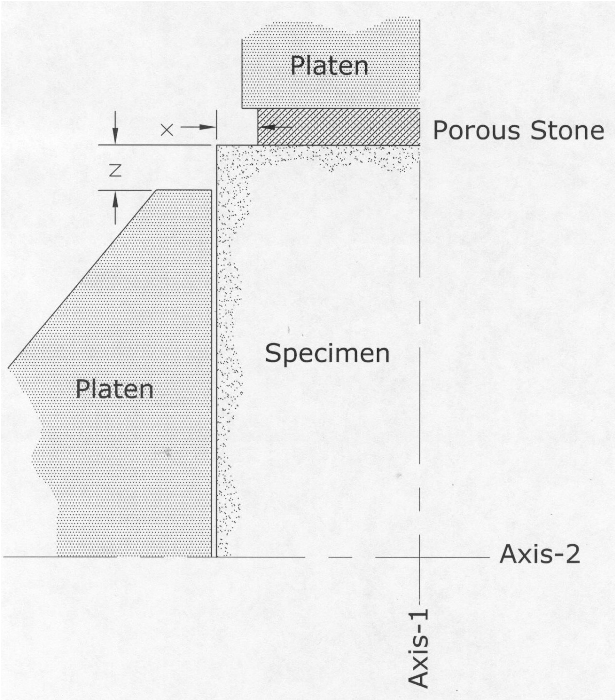
The Poly-Axial Test System includes four hydraulic load rams equipped with LVDT’s so that each platen can be independently computer-controlled. The feedback control can be either stress or strain. With this configuration the specimen can be maintained centered minimizing end platen friction. This is accomplished by always making one of the LVDT’s on each plane with hydraulic loaders the “master” and the opposing LVDT the “slave”. The master LVDT can be controlled to deform at a particular rate, including zero, and the slave is automatically programmed to deform an equal amount.

Each one of the horizontal loading rams has an internal load cell because there can be significant end platen friction at the top and bottom porous stones, especially if the specimen exhibits significant non-homogeneity. The load cell at the bottom vertical loader is omitted because the side platens are smooth and can be lubricated making end platen friction much less an issue for this direction. Pore pressures are measured at the top and bottom specimen ends.

Stresses/strains in the axis 3 directions are applied through the chamber fluid pressure. A volume change device is used to measure and control the strains in this direction. Optional proximity sensors can also be used to measure deformations in this direction.

The chamber with hydraulic loading pistons and specimen in place is shown in the photographs in the front page. The cross sectional dimensions of the specimen are 75 mm by 75 mm, and the height is about 150 mm. The “front” and “back” doors to the chamber are hinged so they swing open for easy access. Each door has a substantial glass or Plexiglas window for viewing the specimen. A seal is accomplished with an o-ring groove and a series of bolts around the periphery of each door.

The chamber itself is mounted on a sturdy table/cart, which can be rolled up to the triaxial test station for testing and storing elsewhere between tests. All the servo valves and other plumbing attachments are mounted beneath the tabletop.



Segment of a poly-axial test specimen

Axis-1 in the figure above is the vertical axis and corresponds to the platens on which the rubber membrane seal is located. The platens are rigid and made of stainless steel. They transition from square near the specimen to circular at the o-ring seal. An internal load cell is rigidly attached to the upper platen on Axis-1. Typically Axis-1 is σ_1 direction when testing undisturbed tube samples, where σ_1 is vertical in the field. Axis-2 in the figure is intended to be horizontal and corresponds to the other set of rigid platens, both of which have internal load cells attached. Typically, Axis-2 direction is the σ_2 direction ($\sigma_2 > \sigma_3$), but this is not a requirement.

The end-platen friction for Axis-1, where the soil contacts the porous stones can be high. On the other hand, the friction is low along Axis -2, where the smooth stainless steel platens contact the outside of the membrane. If desired, applying silicon grease can minimize the friction along Axis-2. The friction for the Axis-3 faces would be zero because the chamber fluid applies the stresses in the Axis-3 direction. Axis-3 direction is perpendicular to the paper and not shown on the figure.

All four hydraulic load rams are equipped with LVDT’s so that each platen can be independently computer-controlled. The feedback for control can be either stress or strain. The advantage of this configuration is that the center of the specimen in the 1-2 plane can be maintained in the center during loading. This will help to keep the specimen centered on the platens. This is accomplished by always making one of the LVDT’s on each plane (with hydraulic loaders) the “master” and the opposing LVDT the “slave”. The master LVDT can be controlled to deform at a particular rate, including zero, and the slave is automatically programmed to deform an equal amount. Thus, if the left platen on Axis-2 moves in toward the center of the specimen a certain amount, the right platen moves the same amount toward the center keeping the center of the contracted specimen always at the original location.

Two internal load cells are placed in the Axis-2 direction to circumvent the errors due to end platen frictions at the porous stones. If the specimen exhibits significant non-homogeneity, the pattern of end platen friction could be unsymmetrical and the left load cell could exhibit slightly different values than the right load cell. Therefore, if the results of the poly-axial test were back-analyzed with a 3D finite element code, the readings from the second load cell could be helpful. To save space, the second load cell was omitted in the Axis-1 direction as the side platens are smooth and can be lubricated. Therefore, end platen friction is much less an issue for this direction.

With this device, as with any other poly-axial device, limits should be imposed on strains and deformations. The segment of specimen shown on the figure indicates the upper limits of deformation, x and z. When these limits are reached, platens overlap and intolerably large transfer of load occurs from one platen to other. If x and z are made too large to increase the limits, the volume of soil at the corner (edge), which experiences only chamber pressure, becomes too large. Therefore, compromised configuration must be chosen. More than one set (and size) of porous stones is provided so that x distance can be adjusted by use of a different set of stones. The distance z can be adjusted by slightly altering the trimmed height of the specimen. Given the flexibility that is intended, it is fair to say that the allowable strains for the proposed system will be as large as for any other poly-axial system, and probably larger than most.

Disadvantages of any poly-axial test are: (1) the stress concentrations at the edges of the platens cause non-uniformities in stress state within the specimen; and (2) the limitations on strain make it difficult to reach the failure state. Both of these disadvantages can be largely overcome by back-analyzing the test results with a 3D finite element code to determine the actual stresses in the specimen.

The apparatus especially well suited to K_o-consolidation testing. The testing system is ideal for the case where Axis-3 (no platens) is assigned for σ_1, and σ_2 & σ_3 are applied through the platens. In this case, the platens would be held stationary to produce K_o conditions, and the only significant strain would be in the Axis-3 direction. For this loading condition, the limitations on platen movement would pose hardly any problem at all. It was assumed that the user will obtain vertical tube samples and that σ_1 will be vertical in the field. If a 50 mm x 50 mm x 100 mm specimen is trimmed from these tubes, long dimension should be vertical corresponding to Axis-1 direction. The other two axes where the strains are held zero for K_o-consolidation will then become σ_2 and σ_3, respectively. The apparatus will function quite satisfactorily for this loading configuration, but the user abide by the limitations to strain in the vertical, σ_1, direction, similar to any other poly-axial apparatus even though this limitation may not be very restrictive. In fact, vertically imposed very large strains would tend to erase the history and memory of the soil and cause it more difficult to measure K_o and/or moduli.

When measuring K_o of a stiff clay, including any differences in K_o in the two perpendicular (horizontal) directions, this apparatus accomplishes the objective properly. This apparatus will serve the purpose in any application for which the apparatus could reasonably be used without companion finite element analyses of the data. If the primary objective were to measure moduli in Axis-2 and Axis-3 directions, then the apparatus could be used for that purpose as well. First, the value of K_o in two perpendicular horizontal directions could be measured, and then moduli in these directions could be measured on the same specimen (procedure is included in GCTS instruction manual).

If the moduli in two perpendicular horizontal directions were different then it would be reasonable to expect the K_o values in these directions to be different. However, the relationship between moduli and K_o values is not well established making it difficult to obtain good estimates of K_o from moduli or moduli ratios alone. For example, measured K_o values depend on the axis strain rate at which they are measured. This dependence was quantified as a part of research supervised by W. N. Houston at U. C. Berkeley about 20 years ago. Triaxial specimens were tested at various fixed axial strain rates (ε_1) keeping ε_2 and ε_3 at zero. The measured K_o value increased with decreasing ε_1. Therefore, ideally, one would measure K_o for various values of ε_1 in the laboratory and then try to estimate the existing vertical strain rate in the field (due perhaps to secondary compression or deposition). The laboratory relationship could then be entered to get an estimate(s) of K_o value(s) in the field.

SPECIFICATIONS

1) SPAX-1000 & 2000 Poly-Axial Testing System

Cubical multi-axial test system with 5 MPa and 1 MPa for the maximum major and minor stresses capacity and independent control of pressure on each of the three specimen axis for a cubical specimens of 75 mm by 75 mm by 150 mm high. Cyclic lateral and axial loading system for cubical specimens. Direct digital servo control of all three principal stresses/strains for performing "true triaxial" tests. Capable of applying or simulating most stress/strain paths found in the field (static or dynamic) including plane strain, K_o, and small shear strains. For the performance and measurement of dynamic shear strength and deformation, liquefaction potential, shear modulus and damping ratio, and other user designed procedures. Complete "turn-key" system.

1.1) SPAX-101 Cubical Cell

Anodize aluminum poly-axial cell mounted on a rolling cart. Accepts cubical specimens of 75 mm by 75 mm by 150 mm high. The Poly-axial cell is capable of applying 5 MPa and 2 MPa for the maximum major and minor stresses respectively maintaining the specimen geometric center static to minimize end platens' friction. Includes:

- (4) Four hydraulic loaders with the following specifications each:
  - 50 mm (2 inch) stroke
  - ± 25 kN Static load capacity
  - ± 20 kN Dynamic load capacity
  - 20 Hertz maximum frequency
  - 100 mm/sec maximum velocity
  - Manifold including low/high pressure control solenoid & accumulator to minimize pressure ripples
  - High-frequency two-stage electro-hydraulic servo valve rated to 19 l/min.
- (4) Four SR-DF-750-1000AC Deformation sensors 50 mm range with 0.25% linearity
- (3) Three SR-LC-LHS-25. ±25 kN (5 kip) submersible load cell with 0.15% precision.
- Lines for top and bottom specimen drainage
- (6) Six feed-through electrical connectors for internal sensors
- Front and back doors with view ports mounted on hinges for easy access to specimen
- Heavy-duty steel table mounted on casters

1.2) SPAX-ACC 75 Test Specimen Accessories

Set of test specimen accessories and end platens with top and bottom pore water pressure ports for cubical specimens of 75 mm by 75 mm by 150 mm high. Includes the following:

- (1) Top and bottom loading platens with porous stones
- (1) Set of rigid lateral loading platens for small strains
- (1) Rigid loading connection for stress reversal
- (12) Latex membranes for cubical specimens
- (2) Set of O-rings for sealing membranes to platens for cubical specimens
- (1) Forming mold for cubical specimens

1.3) PCP-2000 Pressure Control Panel

Pressure/Volume Control System for testing of saturated soil specimens. Includes cabinet mounted on casters to house the confining pressure and back pressure / volume controllers and control panel. Requires input of
clean, dry compressed air. Also includes the following:
- Evacuation chamber with fine spray nozzle and vacuum/vent port for preparing and
storing de-aired water.
- Venturi vacuum pump, vacuum gage and regulator for applying low vacuum to
evacuation chamber.
- Pressure test gauge with (±0.25% accuracy).
- Pressure regulator, and air/water interface for manual control of specimen top back
pressure.
- All necessary plumbing and zero-volume-change valves.
1

1.4) PCP-202-A AUTOMATION PACKAGE

Includes one EP-Pressure Valve for the computer control of the back pressure, one
computer controlled ball valve for specimen drain line and required fittings. Required
for complete automation of triaxial test including Saturation, Consolidation, and Shear
loading stages without user intervention. Maximum pressure: 1000 kPa (150 psi).
NOTE: Requires a 1,000 kPa clean, dry air supply
1.4.2 1