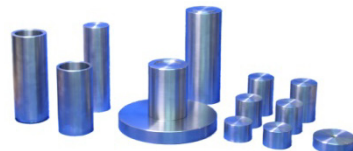


GCTS is committed to designing accurate testing systems by integrating innovative software engineering with advanced hardware. GCTS systems perform at the highest levels of reliability, providing efficient systems that satisfy customer needs and expectations.



► **MRT**
Resilient Modulus Test System



AASHTO T-2 Material Compaction Mold



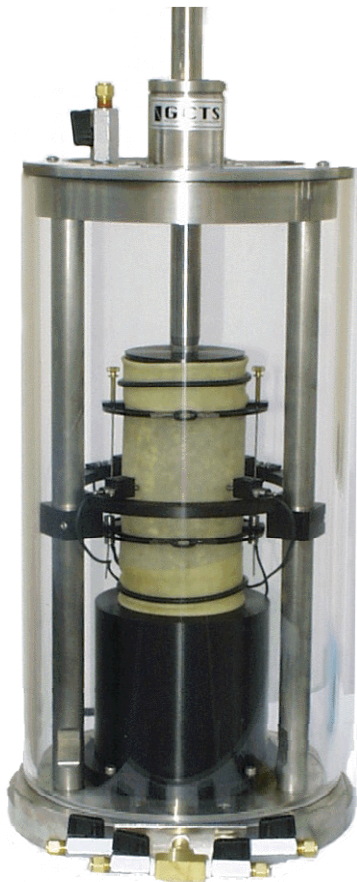
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DESCRIPTION

- **Electro-Hydraulic Digital Servo Control**
- **Easy to use software for automatic test performance & Data Reduction**
- **Meets current AASHTO, SHRP, NCHRP, and ASTM protocols**
- **Triaxial cells for specimens from 71 mm (2.8") to 150 mm (6")**
- **Complete "turn-key" systems**

The GCTS Resilient Modulus Testing System is based on the GCTS Cyclic Triaxial Device with closed-loop control of the axial load/displacement and confining pressure. The device complies with the requirements of AASHTO T 307-99, SHRP-P46, ASTM D3999-91, NCHRP 1-28, and ASTM D5311-92 specifications. The GCTS triaxial cell includes electrical feed-through connectors to accommodate internal instrumentation as may be required by future specifications. GCTS is also committed to updating its control software whenever new specifications are published. The GCTS Resilient Modulus Testing System can also be used to perform other dynamic and static tests such as liquefaction, cyclic strength, Stress Path, Ko-Consolidation, as well as conventional UU, CU, and CD tests.

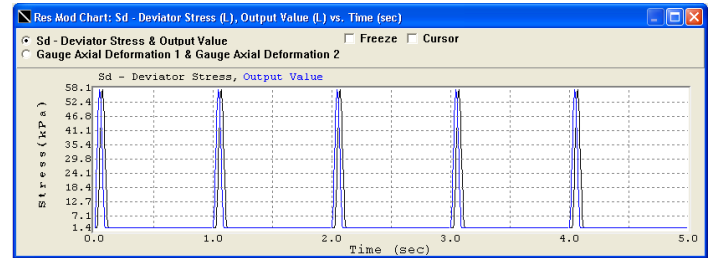
The GCTS Resilient Modulus Testing System is designed to be easy and convenient to use. The triaxial cell uses an external cell wall that allows setup of the specimen or any internal instrumentation without removing the triaxial cell top or loading shaft. The GCTS triaxial cell has a graphite seal to minimize errors arising from friction on the loading shaft. Even though this seal friction is typically less than 4 N (1 lb), an internal load cell is included to be used with "soft" specimens or where the required precision or specification demands it.



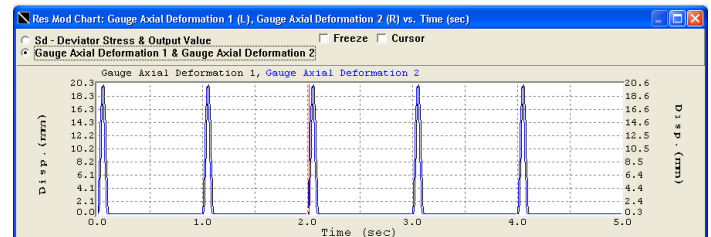
Triaxial Cell with Optional Internal Axial and Radial Deformation Sensors

An important consideration in the design of the Cyclic Triaxial Testing System is the achievement of the specified load or displacements at high frequencies. This is especially difficult during the performance of a Resilient Modulus test where the specified cyclic amplitudes vary greatly for the different loading sequences. The loading system must be relatively stiff and have sufficient flow capacity to achieve the displacement amplitudes that the specimen is subjected to for a given cyclic load. It must also be capable of self-adjusting to prevent the load from over or under shooting. GCTS offers its new "Adaptive

Control Software" for the resilient modulus test to improve the control precision without user intervention. In addition, GCTS provides a 16-bit resolution Analog-to-Digital converter with 250,000 Hz sampling rate with "sample-and-hold" to enhance accuracy and eliminate data skew.



Prescribed and Actual Load Real-Time Plot



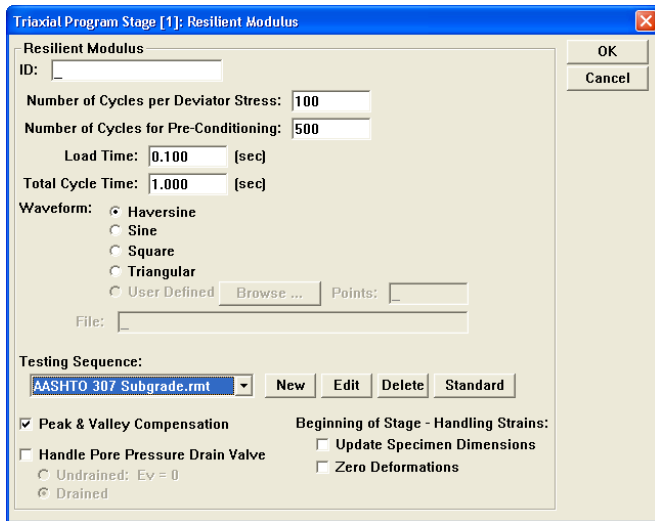
Real-Time Plot of Both Deformation Sensors

Another consideration to the control precision is the flow capacity of the hydraulic pump system. Most GCTS Resilient Modulus Testing Systems are designed with a 5 GPM constant pressure/variable volume hydraulic pump as well as a 1,900 cc (116 cubic inches) accumulator. The above hydraulic system is adequate given the relatively small displacements that typical specimens undergo during Resilient Modulus testing. Hydraulic power supplies with larger flow capacities can also be supplied if required for other cyclic tests. Included performance charts show the peak-to-peak displacement vs. frequency curves for different flow capacities for all four GCTS Resilient Modulus systems. These curves were obtained for ideal conditions under zero load.

The proposed system also includes precise servo-control of the cell pressure. Automatic cell pressure control enables the system to perform a complete Resilient Modulus test without user intervention. This feature is especially important when performing Resilient Modulus tests because of the various load sequences with different cell pressures required by the test specifications.

GCTS offers four standard Resilient Modulus systems for testing different size specimens. The MRT-50 and MRT-100 Systems can test specimens with a 70 mm (2.8 inch) diameter. The MRT-200 is capable of testing specimens with 100 mm (4 inch) diameter and also

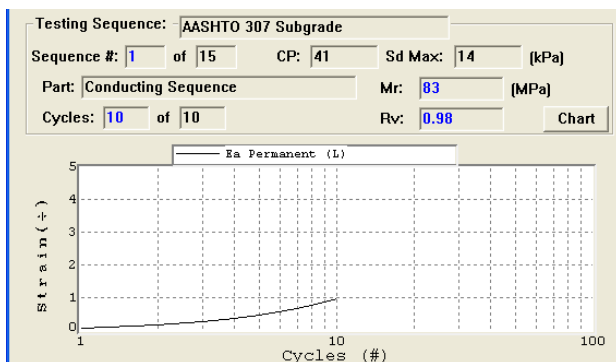
70 mm (2.8 inch) diameter. The MRT-300 system can accommodate specimens with 150 mm (6 inch) diameter and 350 mm (15 inch) height.



Resilient Modulus Test Setup Screen

The MRT-300 can also test specimens with 100 mm (4 inch) and 70 mm (2.8 inch) diameter although it is recommended to use a smaller cell for 70-mm diameter specimens. For low budgets, GCTS also offers the MRT-50 Electro-Pneumatic Resilient Modulus system sold at very affordable prices. All standard systems include required dual external deformation sensors with supports and internal load cell.

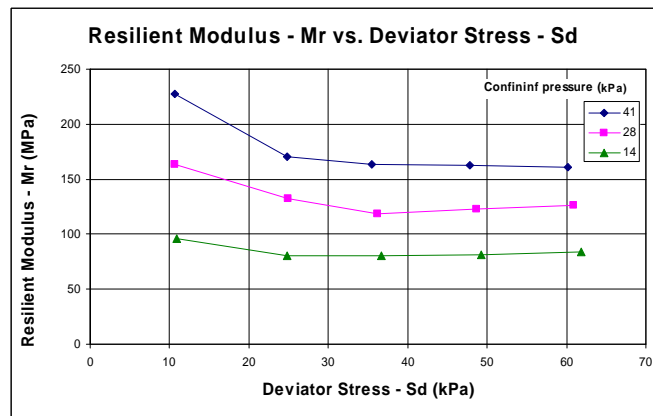
An optional environmental chamber can be provided to test asphalt specimens in either Triaxial or Indirect Tension mode. Test temperatures from -15 °C (-30 °C with the use of a nitrogen tank) to +60 °C can be achieved with this option. Our Indirect Tension Resilient Modulus software in accordance with ASTM D4123 and SHRP-P7 protocols is provided with this option. Other options include the GCTS Asphalt Coring machine and Lab Saw to eliminate uneven distribution of air voids in compacted specimens. Also available is the Ultrasonic Velocity measurement system for soil or asphalt specimens.



Permanent Deformation versus Cycle Number

The GCTS *Resilient Modulus* software features built in AASTHO, SHRP, and NCHRP test sequences, and the capability to specify user defined sequences. Contact stress is automatically adjusted according to the above procedures as selected. Available waveforms include haversine, sine, square and triangular, along with a user defined waveform selection. Optional peak & valley compensation ensures proper and quick matching of the load parameters. Real time displays of the prescribed versus actual dynamic load or the dynamic deformation measurements by each sensor are always present. Deformation ratio of the two sensors, R_v (to ensure that the two deformation sensors are in agreement) and M_r are also calculated in real time. During export, curve fitting is done to fit the results to models that predict M_r as a function of σ_m , σ_d , and CP (cell pressure). Four different functions are calculated automatically (as required by AASTHO and NCHRP procedures):

- $M_r = K_1 (\sigma_m)^{K_2}$
- $M_r = K_1 (\sigma_d)^{K_2}$
- $M_r = K_1 (\sigma_d)^{K_2} CP^{K_3}$
- $M_r = K_1 Pa[(\Theta - 3K_6)/Pa]^{K_2} [\tau_{oc}/Pa + K_7]^{K_3}$



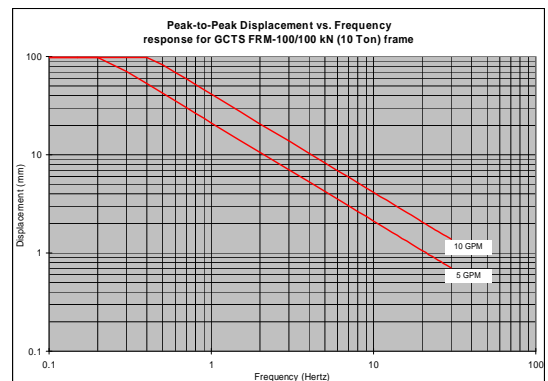
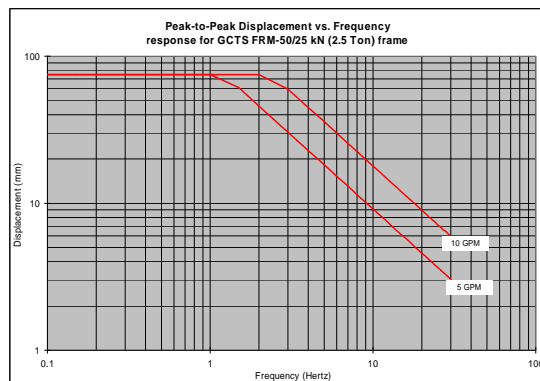
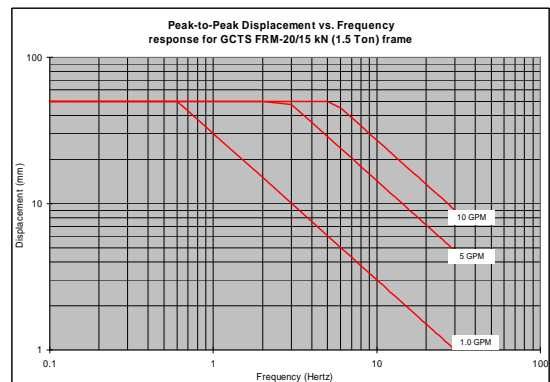
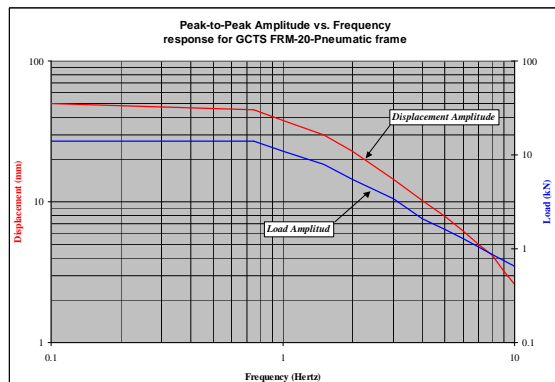
Test Results

This GCTS Device is a sound and well-integrated system designed specifically to perform Resilient Modulus tests as well as other tests such as the Complex Modulus test. The equipment offered by GCTS includes a complete, "turn-key" system to perform Resilient Modulus tests. GCTS engineers have been working closely for the last 10 years with many Departments of Transportation and research centers in the development of the Resilient Modulus standards. GCTS engineers have the geotechnical background and many years of experience in the design and construction of servo controlled testing devices to supply and support the best option for a Resilient Modulus Device.

SPECIFICATIONS

	MRT-50	MRT-100	MRT-200	MRT-300
<u>Load Frame</u>				
Model:	FRM-20	FRM-20	FRM-50	FRM-100
Static load capacity:	14 kN	22 kN	45 kN	100 kN
Rated dynamic load capacity:	*	19 kN	38 kN	85 kN
Actuator type:	pneumatic	hydraulic	hydraulic	hydraulic
Stroke:	50 mm	50 mm	100 mm	100 mm
Maximum vertical daylight opening:	765 mm	765 mm	900 mm	1,050 mm
Horizontal daylight opening:	340 mm	340 mm	355 mm	405 mm
<u>Triaxial Cell</u>				
Model:	TRX-100	TRX-100	TRX-200	TRX-300
Maximum specimen diameter:	75 mm	75 mm	100 mm	150 mm
Maximum specimen height:	190 mm	190 mm	250 mm	375 mm
Loading piston diameter:	15.9 mm	15.9 mm	25.4 mm	25.4 mm
Diameter of platens & accessories included:	70 mm	70 mm	100 mm	150 mm
<u>Transducers Ranges</u>				
Frame LVDT:	50 mm	50 mm	100 mm	100 mm
External load cell:	±14 kN	±22 kN	±45 kN	±100 kN
Internal load cell:	±2.2 kN	±2.2 kN	±8 kN	±22 kN
Axial LVDTs (2):	±1.0 mm	±1.0 mm	±2.5 mm	±6 mm
Cell pressure transducer:	1,000 kPa	1,000 kPa	1,000 kPa	1,000 kPa
Standard shipping volume:	1.2 m ³	2.3 m ³	2.6 m ³	3.0 m ³
Standard shipping weight:	200 kg	750 kg	980 kg	1,200 kg

PERFORMANCE



*NOTE: The maximum displacement amplitude curve for the MRT-50 was obtained under zero load and the dynamic load amplitude curve was obtained for small displacements. The dynamic load amplitudes for the above hydraulic systems are equal to the rated dynamic load capacity for frequencies up to 20 Hz.

STANDARD FEATURES

1.1) Load Frame

Two column vertical standing assembly with threaded columns for crosshead adjustment. Includes double acting electro-hydraulic cylinder and hydraulic servo valve for closed-loop control of axial load or axial displacement (pneumatic loader and servo valve for the MRT-50)

1.2) Triaxial Cell

Three-column stainless steel construction with external acrylic plastic cell wall. 1,000 kPa (water) / 250 kPa (air) lateral confining pressure capacity. Includes lines for top and bottom specimen drainage, stainless steel loading piston, ball bushing guide, *low-friction* (under 10 N) graphite seal, and sealed feed-through connectors to accommodate different type of sensors such as load cells, LVDTs, ultrasonic transducers, etc. Also includes plugs for sealing the feed-through connectors while not in use. Accepts samples with a length of 2.0 to 2.5 times the diameter. Supplied with valves, fittings and nylon tubing.

1.3) Test Specimen Accessories

Set of test specimen accessories and end platens with top and bottom pore water pressure ports including the following:

- (1) Top and bottom platens with embedded porous stones.
- (1) Spherical seat loading connection set.
- (1) Rigid loading connection for stress reversal.
- (1) Holder plate for two external LVDTs.
- (12) Latex membranes.
- (2) Set of O-rings for sealing membranes to platens.

1.4) PCP-201 Computer Controlled Cell Pressure

Includes one EP-Valve and required fittings. Requires a 1,000 kPa clean, dry air supply.

1.5) Transducers

The following sensors are included to measure Axial Load, Axial Deformation, and Confining Pressure.

- (1) External Load Cell.
- (1) Internal Load Cell.
- (2) Small Strain Deformation sensors.
- (1) Frame Deformation sensor.
- (1) Confining Pressure Transducer 1,00 kPa range.

1.6) SCON-1500. Digital Signal Conditioning and Servo Controller System

Microprocessor based digital servo controller, function generator, data acquisition, and digital I/O unit. Advanced servo control from any system sensor with "on-the-fly bump-less" transfer switching between any connected transducer or calculated input.

- 850 MHz micro-processor with 64 MB RAM and 64 MB solid state disk.
- 6 kHz maximum loop rate (250 kHz conversion rate between channels). 16-bit resolution.
- Adaptive digital servo control.
- Accepts up to 8 DSB-111 universal signal conditioning boards and up to 4 control channels (DSB-121 and DSB-122 boards).
- 4 digital inputs, 4 digital outputs, and 48-bit digital counter.
- Watchdog timer to detect control program status for automatic interlock shutdown.
- Ethernet and RS-232 Communications.

1.7) DSB-111. Universal Signal Conditioning Boards (6 each).

Includes 6 universal signal conditioning boards for load cells, LVDTs, pressure transducers, thermocouples, or other analog input signals. Each module includes digital (computer) controlled offset and gain.

- 16-bit resolution.
- Adjustable offset range: +/- 5 volts.

- Adjustable gain range: 1 to 1000 in 4000 steps.
- +/-5 volt DC excitation.
- 5 Volt RMS @ 3kHz AC excitation.
- 6-pole anti-alias filter with 0-50 Hz flat response with less than 0.009 dB ripple and more than 60 dB attenuation at frequencies larger than 500 Hz.

1.8) DSB-122. Servo Amplifier Boards (2 each).

Includes 2 servo amplifier boards to drive servo valves for the digital control of axial load/deformations and cell pressure. 16-bit resolution and 325 mA maximum output servo amplifier board to drive servo valves. Each board includes null, gain, dither amplitude, dither frequency, and current limit adjustments.

1.9) WIN-CATS Software.

32-bit Windows 98/2000/NT/XP software for advanced digital servo control from any system sensor or calculated channel with "on-the-fly" bump-less transfer. Includes calculated channels for stress, strain, etc. and user defined equations.

- Third degree polynomial conversions from sensor output in real time.
- Ability to define user defined inputs as a function of other inputs and correct by another input via a third degree polynomial to view or control in real time.
- Configurable unit library to automatically perform unit conversions.
- Linear, log, and semi-log plotting capability with user specified plot parameters.
- Unlimited user configurable view tools (meters, gages, bars, etc.)
- Signal analysis option that will give FFT of any system signal.
- Advanced PID control with adaptive control.
- Peak/Valley compensation on system control.
- Stabilization by any associated input in control, not only the feedback control sensor
- Synchronized control of up to 3 servo channels.
- Timed, Level Crossing, and Peak/Valley data acquisition modes.
- X-Y and Strip Chart type real-time graphical display.
- Allows creation of an unlimited variety of wave forms including user generated profiles such as a digitized earthquake record.
- Digital Signal Processing and spectral analysis of real-time data.
- Easily created cyclic and static customized test procedures.
- Automatic "smooth" control transfer from/to any sensor.

1.10) WIN-TRX-MR Resilient Modulus of Unbound Granular

Base/Subbase Materials and Subgrade Soils. Includes automated test control and report generation according to AASHTO T-274, AASHTO T-307 (99), NCHRP 1-28, and SHRP P46 as well as user definable test procedures.

1.11) WIN-TRX

Triaxial test module to automatically perform conventional triaxial static tests as well as other advanced test procedures.

1.12) HPS-10-5-A Electro-Hydraulic Pump System

19 LPM (5 GPM), 10 HP, 21 MPa variable volume constant pressure pump. 100 liter reservoir, oil temperature indicator, pressure and return filters, pressure gage, valves, thermal and low fluid level shut off protection, heat exchanger, hydraulic hoses, accumulator, filler strainer, drain port and motor starter. Includes computer Low/High/off pressure controls, filter service auto diagnostics and maintenance scheduling. Standard power: 230 V/ 3-phase / 60 Hz (Other power available. Please specify electrical power if different). *Not included with MRT-50 Pneumatic System.*

1.13) Computer System

OPTIONS

2) Pressure Control Panel

2.1) PCP-200 Pressure Control Panel & Volume Change Device.

Complete pressure control for triaxial system. Dual use volume change device for triaxial and permeability testing. 150-cc capacity and 0.01 cc resolution. Graded water level sight tubes for electronic and manual readings. Includes mounting platform for pressure transducers and necessary plumbing. Meets ASTM D3999-91 and D5311-92 pore water pressure measurement compliance requirements. Includes regulators for manual pressure control, precision pressure gage with 1 kPa resolution, regulated air supply to servo valve(s), venturi vacuum pump, and necessary valves. 1,000 kPa pressure capacity. Requires clean, dry compressed air.

2.2) Transducers

The following sensors and signal conditioning modules are included to measure Pore/Back pressure, and volume change:

- (1) Differential Pressure Trans. 1,000 kPa range.
- (1) Differential Pressure Trans. 900 mm H₂O range.

2.3) Signal Conditioning

Two DSB-111 Universal Signal Conditioning boards for above transducers.

3) PCP-202-A Back Pressure Servo Control

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

4) Compaction Split Molds

Forming mold/jacket stretcher for specimens with a height of 2.0 times the diameter. Anodized aluminum construction with vacuum ports to distribute vacuum throughout the inner surface of the mold for even membrane expansion. Available sizes for 70 mm (2.8"), 100 mm (4"), and 150 mm (6") diameter specimens.

5) Accessories for Other Diameter Test Specimen

Set of test specimen accessories and end platens with pore water pressure ports including the following:

- (1) Set of Top/Bottom platens.
- (1) Set of porous stones (top/bottom).
- (12) Latex membranes.
- (2) Set of O-rings for sealing membranes to platens.

6) ECH-30 Environmental Chamber

Environmental chamber for cooling and heating with -30 °C to +180 °C range. Inside dimensions: 30" high, 15" wide and 17" deep (requires liquid nitrogen tank for cooling). Accepts triaxial cell or indirect tension fixture. Includes metallic reinforcement rings for triaxial cell wall.

7) Platens for 100 mm (4") by 150 mm (6") Asphalt Specimens

Set of smooth bottom and top specimen platens for 100-mm diameter by 150-mm height specimens to be used in the TRX-200 or TRX-300 Triaxial cell.

8) Internal Axial Measurement Device

Transducer supports for the internal measurement of axial strains inside the triaxial cell and directly mounted on the specimen. Includes two axial LVDT holder rings. One set required for each specimen diameter.

9) Radial Measurement Device for 150 mm and 100 mm specimens

For the measurement of radial strains inside the triaxial cell. Includes four LVDTs ±2.5 mm (0.1") range for radial measurements on 4 places at 90 degrees each. Also includes four signal conditioning modules for LVDTs, four radial LVDT holders for 150 mm specimens, 4 radial LVDT holders for 100 mm specimens, and four sealed feed-through connectors for LVDTs.

10) FRM-100-IND-A Indirect Tension Fixture To Perform Resilient Modulus Test for Asphalt

Indirect tension diametral yoke for 100 mm (4") diameter by 64 mm (2.5") thick asphalt concrete specimens. Includes upper and lower platens constrained to remain parallel during testing and two transducer holders to position transducers at the specimen mid-height. Meets ASTM D4123-82 specification.

11) ACD-100 Pressure Controlled Coring Machine

1.5 HP electric motor with 12 adjustable spindle speeds from 150 through 4,200 rpm. Drilling rate controlled by both pressure and speed eliminating the tendency for aggregates to move. Includes 100 mm (4") diameter diamond core barrel for specimens up to 250 mm long. Rigid Multi-Column drill support frame eliminates ridges on specimen. Comes with specimen holder for coring 100 mm (4") specimens from 150 mm (6") compacted samples. Hydraulic pump, water swivel, drip pan, vise table, and motor head assembly also included. Operation: 110 or 230 Volts/60 Hertz/Single Phase (please specify). Other diameter core barrels available.

12) RLS-100 Asphalt Lab Saw

Automatic asphalt core saw with three-speed hydraulic power feed from 230 through 340 mm/hour and automatic cut off adjustable for length of cut. Accepts cores up to 175 mm (7 inch) in diameter. Includes 3 HP/220 Volt electric motor, metal hood with viewing window, and 800 rpm approximate blade speed. Includes 455 mm diameter asphalt blade and stainless steel option to use water to cool the saw blade for cutting specimens that may react to coolant fluids other than water.

13) Internal/External Load Cell (5, 10 or 20 kN)

Low profile load cell with 5, 10 or 20 kN range and 0.05% accuracy. Includes shunt calibration.

14) External Load Cell (50 or 100 kN)

Low profile external load cell with 50 kN or 100 kN range and 0.05% accuracy. Includes shunt calibration.

15) DCD-25 LVDT Calibrator

25.4 mm (1") travel range and 0.001-mm (0.000050") resolution. Measures absolute or relative displacements in SI or English units. Accepts most LVDTs. Includes calibration certification and set of adaptors to hold transducer bodies of various diameters.