



RHEOLOGICAL PROPERTIES

KINEXUS DSR SERIES

REDEFINING RHEOMETER CAPABILITIES FOR
ASPHALT BINDER AND BITUMEN TESTING

ASPHALT BINDER AND BITUMEN

Characterization and classification to asphalt industry standards



Asphalt, or bitumen, is a petroleum product used in the road (pavement), roofing and construction industries. A mixture of aromatic hydrocarbons (varying with geographical source), this black viscoelastic material is considered to be a complex colloidal system.

Asphalt is used as a binder with aggregates in road (pavement) construction and as such determines performance and lifetime. Additives such as polymers, crumb rubber, oils, waxes, phosphates and pH adjusters are used to enhance mechanical properties in modified asphalt binders. Asphalt emulsions are also used as water-proofing and re-surfacing materials.

Rheological characterization by Dynamic Shear Rheometers (DSR) is the standard method of classifying asphalt binders for behavior over time and loading conditions, and in different climates.



While some still use viscosity (vis) and penetration (pen) methods for grading, the use of DSR grading methods provides a much broader range of information about the asphalt performance properties and its suitability for desired applications. This is especially the case with engineered binders; binders designed with elastomeric properties to reduce rutting, aging, thermal and fatigue cracking.



Rheological testing with the Kinexus DSR Series

- Grade testing to industry standards such as AASHTO , ASTM and EN specifications (see www.malvern.com/kinexus for a full list)
- Full characterization of rheological behavior with Master Curves
- Formulation development and quality control metrics
- Determination of Mixing and Compaction Temperatures
- Blend testing of Warm Mix, Crumb Rubber and Recycled Asphalt Paving (RAP)
- Solids testing for Fatigue or Accumulated Strain
- Emulsion stability and viscosity profiling
- Benchmarking and comparison of competitive products
- Penetration, pull off and tack testing
- Tribology-friction testing
- Additive optimization and product interactions



KINEXUS DSR SERIES

Redefining rheometer capabilities for Asphalt binder and bitumen testing

The Kinexus DSR Series is the next generation rotational rheometer platform for Asphalt testing that's been developed from extensive market knowledge and feedback, integrating innovative instrument design with a revolutionary software interface, to deliver an intelligent solution that will exceed your rheological expectations.

A modular rheometer with true 'plug and play' functionality for all measuring systems and environmental control units. The Kinexus DSR Series enables pioneering Standard Operating Procedure (SOP) based testing with a built-in comprehensive library of standard test protocols for the Asphalt industry.

TruGrade_0001 Auto-grade T315 Original Binder.rseq
 TruGrade_0002 Auto-grade T315 Rolling Thin Film Oven Binder
 TruGrade_0003 Auto-grade T315 Pressure Aging Vessel Binder
 Texas SPG TruGrade_0001 Auto-grade T315 Original Binder
 AASHTO_0001-1 T-315 Original Binder
 AASHTO_0001-2 T-315 Original Binder auto report print
 AASHTO_0001-3 T-315 Nevada Original Binder
 AASHTO_0001-4 T-315 Texas SPG Original Binder
 AASHTO_0002-1 T-315 Rolling Thin Film Oven
 AASHTO_0002-2 T-315 RTFO Binder auto report print
 AASHTO_0003-1 T-315 Pressure Aging Vessel
 AASHTO_0004 T-315 Cannon Oil Verification DSR test
 AASHTO_0005 T-315 Linearity Test
 AASHTO_0006 T-315 Cannon Oil Statistical Quality Control Documentation and
 AASHTO_0007-1 TP-70 Multiple Stress Creep Recovery
 AASHTO_0007-2 T350 Multiple Stress Creep Recovery
 AASHTO_0007-3 Combined T315 and T350
 AASHTO_0008-1 TP-70 Multiple Stress Creep Recovery Using Bohlin Data
 AASHTO_0008-2 T-350 Multiple Stress Creep Recovery Using Bohlin Data
 AASHTO_0008-3 Manual Entry MSCR Elastic Response Analysis
 AASHTO_0009 TP-101-12-UL LAS Test for asphalt fatigue
 ASTM D4402 Brookfield Viscosity
 Mix and Compaction Temperature Shear Flow - Renike Method
 Mix and Compaction Temperature Phase Angle - Casola Method
 Mix and Compaction Temperature Equi-Viscosity - Brookfield Method.rseq
 Master Curve Generation with Cross Over Analysis
 Softening Point Determination
 BYET Binder Yield Energy Test Method A

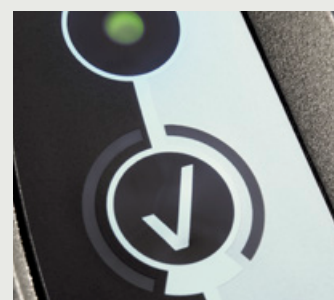


Key benefits of the Kinexus rheometer

- All modes of operation – stress, shear rate and direct strain controlled oscillation
- Exceptional vertical travel and gapping capabilities with ultra-responsive and highly sensitive Normal Force for dedicated pull-off, tack and penetration testing
- Unique rSpace software interface that offers total flexibility of test set-up, from sequence-driven Standard Operating Procedure (SOP)-type functionality to fully customizable test design
- Fully integrated Materials Database enables user friendly data management that can be tailored to any organization. Easily tie results by products, projects, customers, vendors, tanks, or locations. Maintain testing logs and specification limits for acceptance
- Wide variety of measurement geometries optimized for rheological characterization of liquid binders to solid asphalt cores
- Complete sample history recorded from loading to unloading, ensuring reliable and reproducible measurements
- Unique 'plug and play' cartridge system for all environmental controllers – all mechanical, power, communication and fluid connections made in one simple action. Capable of fully automated calibration
- Geometry Database in conjunction with RFID plate recognition ensures only the correct, in tolerance, plates are used for testing
- Fully automated statistical quality control (SQC) charting with pass/fail analysis tied to any sample



Environmental cartridges are easily changed or removed for service



Large, interactive, operator inputs are glove friendly and solvent safe

UNPRECEDENTED DUAL-ACTION CAPABILITIES

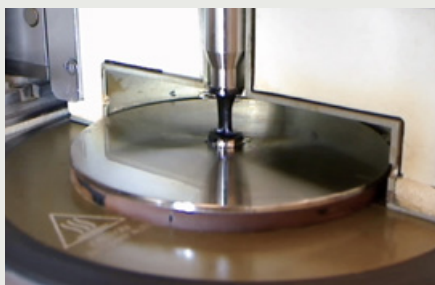
A revolution in shear and vertical (axial) test control

The unique combination of Kinexus DSR hardware technology and rSpace software gives the user the ability to configure three critical rheometer functions independently:

- Rotational (shear) control - torque, speed and position
- Vertical (axial) control – gap and Normal Force
- Temperature control

Offering the ultimate in rheological test flexibility for both industry and academia, Kinexus DSR enables:

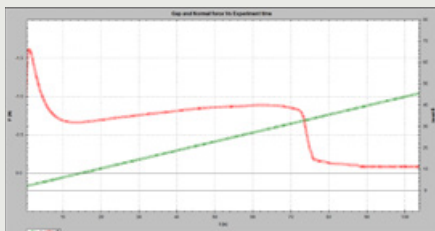
- All rotational shear-based testing
- Advanced vertical (axial) testing including pull-off, squeeze flow and tack testing
- A combination of shear and vertical actions for revolutionary process-relevant measurements



Significant design effort has been directed at the vertical, or axial capabilities of the Kinexus DSR platform – an area that typically sees compromises on most rheometer systems.

Kinexus DSR combines high speed and ultra-fine resolution gap control with high sensitivity and ultra-responsive Normal Force control for truly innovative sample loading and measurement capabilities – from sensitive structures to rapid curing systems.

Allied to 'cradle to grave' data collection providing a complete sample history from loading to unloading, every aspect of rheological testing can be optimized and verified for total consistency.



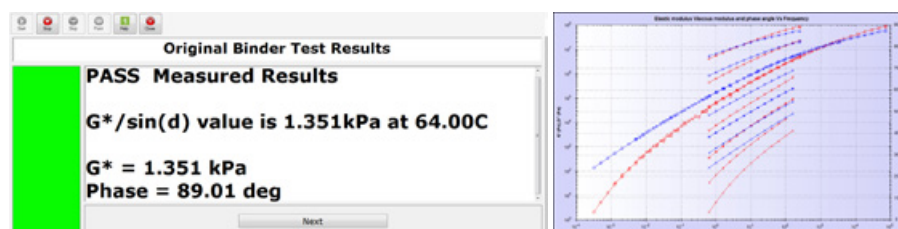
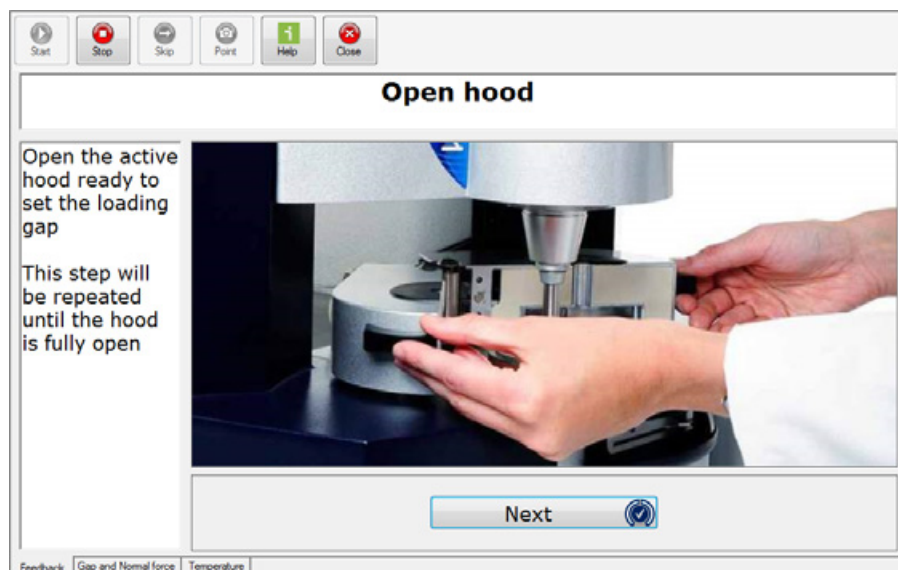
rSPACE SOFTWARE

Standard Operating Procedure (SOP) driven tests for robust rheological measurements

Malvern's Standard Operating Procedure (SOP) approach to material testing has been a cornerstone to all our technologies, and is now available for the first time on a rheometer system.

rSpace can be used for simple QC operation or for advanced rheological testing

- Locked down tests including geometry and parameter set-up using standard user access control
- Continuous feedback and user guidance at all times
- Ensure best rheological practice
- Add specific test controls relevant to your samples
- Produce standard test methods for your samples
- Available for use company-wide
- Consistent operator independent testing as standard
- Time-Temperature Superposition for master curve generation
- Automatically reports Pass or Fail based on the appropriate test and test criteria
- Report designer with auto print/PDF generation



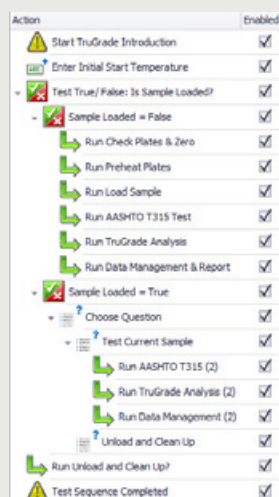
Clear operator feedback of relevant information and visual properties

Automated advanced analysis available

rSpace - Powerful, user friendly, flexible and easily tailored

rSpace software is driven by 'sequences' – which consist of fundamental rheological actions (or test building blocks) that can be linked together with other test actions, such as user feedback and choices, calculate values, loops and triggers, in order to build 'intelligent' tests.

- Set a sequence to 'run' only, and a user operates under SOP-type conditions with defined test instructions and feedback
- Set user access to 'edit' sequence functionality, and researchers have the full design capabilities at their fingertips



'What rheological test progression would you like to run?'

- You think it - Kinexus can run it
- Dedicated and advanced tests exactly to your needs

Program sequence in Kinexus

- 'Drag and drop' actions and 'Import subsequence' functionality
- Include user choices, calculate values, loops, triggers
- Include specific user inputs and instructions as required
- Include specific analysis, acceptance criteria and 'what next' decision making

TECHNOLOGY AT THE HEART OF KINEXUS DSR

10 Features of the Kinexus DSR series

1. Inductive motor technology

Precision control of instrument torque

- Ultra low inertia, electronically commutated (EC), drag cup motor allows rapid change of torque and speed, as well as, access to higher oscillation frequencies without the need of excessive corrections.
- Wide continuous torque range facilitates measurement of low viscosity liquids through to stiff solids without changing test conditions or measuring geometries.
- Intelligent motor cooling regulates internal operating temperature according to torque and power demands.

2. Precision air bearing

Provides frictionless support between moving parts

- Machined from sintered, porous carbon to provide uniform air distribution with negligible directional bias enabling operational and measurable torques below 1 nNm.
- High axial and radial stiffness for increased robustness and reduced compliance.

3. High Precision Rotational System

Accurate measurement of rotor position and speed

- Optical encoder with nanometer resolution for measuring minuscule radial displacements and speeds.
- Sample response optimized by locating the sensor as close to the measurement as possible.
- High speed Digital Signal Processor (DSP) provides rapid and accurate direct strain and speed control.

4. Precision chuck mechanism

Connects and aligns the measuring system with the motor and bearing assembly

- Quick connect push-fit mechanism for easy insertion and removal of measuring systems while maintaining micrometer alignment.
- Auto recognition - Radio frequency identification (RFID) reader automatically identifies the measuring systems, calibration constants and operational settings, and ensures zero gapping prior to measurement.

5. Upper measuring system

Interfaces with the sample to transfer torque or motion from the motor assembly

- Wide range of measuring systems available, including plates, cones, cylinders and vanes with different sizes, materials and surface finishes.
- Precision engineered for accurate calculation of rheological parameters and designed with high shaft stiffness and low mass to minimize compliance and inertia.
- Quick connect push-fit design and integrated RFID tag (auto-detection) allows for reduced time to measurement while ensuring the correct measuring system and calibration constants are always used.

6. Axial Force Sensors

Provides the measurement and control of normal force

- Novel strain gauge with fast transient response which is independent of air bearing rotor position and rotor speed.
- Operational in all modes of instrument operation for both measurements and control. Capable of measuring between 0.001 and 50N for consistent sample loading and precision control of axial testing.

7. Stage Drive Control

Controlled vertical profiles for sample loading and axial testing

- Enables full range of vertical profiles including linear, exponential and normal force over a working range of 230 mm (0.1 μm resolution) and speed range of 0.1 $\mu\text{m/s}$ to 35 mm/s for controlled sample loading or dedicated axial testing.

8. Integrated electronics

Houses all electronics for controlling rheometer functionality

- All micro electronics are located as close to the measurement as possible, improving measurement quality and reliability.
- Incorporates all control and measurement functions including high speed Digital Signal Processor (DSP), which provides the intelligence to the instrument.

9. Environmental control cartridge / Lower measuring system

Provides fast lower geometry interchange, plus temperature and environmental control

- Unique 'plug and play' cartridge system with auto-recognition. All mechanical, power, communication and fluid connections made in one simple action.
- Cartridge options include:
 - Asphalt Peltier Plate, active hood design
 - Universal Cylinder; for cub-bob & torsion
 - High Temperature; for polymer melts & curing.
- Geometries available in a wide range of sizes, materials and surface finishes.
- Lower measuring system can be secured and removed easily using a simple slide lock mechanism, while maintaining micrometer alignment.
- Employs Peltier elements for heating/cooling of upper and lower plates working in conjunction with an intelligent heat exchanger to improve efficiency.
- Optimally positioned temperature sensors (PT100s) ensure fast & accurate sample temperature reporting.

10. Control Panel

Allows rheometer functions to be controlled direct from the instrument

- Control panel functionality directly linked to all user instructions in test sequences so 'Yes' and 'No' responses to software prompts can be made without keyboard interaction.
- Warning lights flag-up any rheometer faults, software communication errors or low pressure in the air bearing.
- Robust design for glove operation and solvent safe for easy clean up.

TAKE A CLOSER LOOK



MEASURING SYSTEMS AND ACCESSORIES

Characterization and classification to asphalt industry standards

Active Hood Cartridge [-40 °C to +200 °C] Environmental controller with minimized thermal gradients for plate measuring systems

- Applicable to the measurement of highly thermally-sensitive samples, and for temperature-critical testing
- Proprietary design incorporates state-of-the-art heating technology with Peltier elements to dynamically control radial and vertical thermal gradients within the sample quickly and accurately
- Conforms to AASHTO, ASTM & EN standards
- Temperature resolution to better than 0.0005 °C
- PT100 sensor located within 1 mm of asphalt sample for accurate reporting
- Low thermal mass components for rapid response
- Inlet for inert gas feed into sample chamber enables live monitoring of aging
- Easy and accurate integrated temperature calibration



Peltier Cylinder Cartridge [-30 °C to +200 °C]

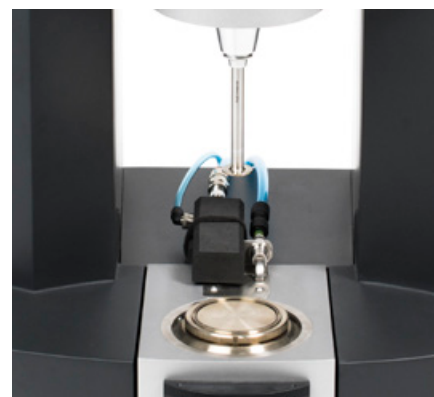
Environmental controller for concentric cylinder-type measuring systems

- Twin Peltier design for rapid temperature changes, sample equilibration and minimal thermal gradients
- Various cup and bob sizes available - C14 (DIN), C25 (DIN) and wide diameter C34
- Interchangeable lower cups with removable base for ease of cleaning
- Plate insert provides a 'universal Peltier option'
- Accommodates Solid (Torsion) Fixtures for Dynamic Mechanical Analysis (DMA) testing of solid asphalt cores
- Crumb rubber testing system available
- Easy and accurate integrated temperature calibration



High Temperature Cartridge (HTC) [0 °C to +300 °C] High temperature environmental controller for cone-plate and parallel plate measuring systems

- Extremely stable temperature control using a high accuracy PT100 sensor in close proximity to sample
- Rapid temperature changes of up to 20 °C per minute.
- Temperature resolution to better than 0.0005 °C
- Air cooling and adiabatic cooling for rapidly attaining ambient and sub-ambient temperatures
- Easy and accurate integrated temperature calibration
- All plate and cone diameters are available
- Optional disposable plate inserts available for curing applications



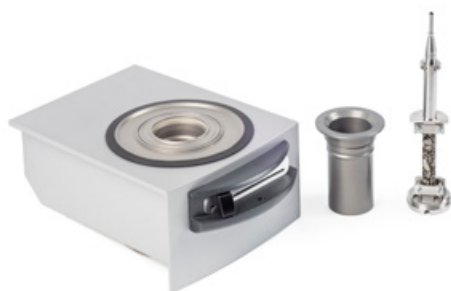
KINEXUS DSR ACCESSORY SPECIFICATIONS

Characterization and classification to asphalt industry standards



Measuring systems

- Quick-connect geometries with intelligent RFID auto-recognition linked to database
- Lock-down tests to specific geometry to minimize operator error
- Standard upper plates of 4 mm, 8 mm, and 25 mm to conform to AASHTO, ASTM & EN standards, with disposable options also available
- Coaxial cylinders (cup and bob) to DIN standard with Double gap and vane tool options also available
- Geometry adapter allows use of custom geometries (e.g. Penetration probes)
- Automatic temperature calibration device available
- Tribology kit for friction testing, lubricity and warm mix analysis
- Torsion kit for solids testing



Solid Fixtures (-20 °C to +200 °C dry and fluid immersed (wet))

Torsion/DMA System including Sample Mounting & Alignment kit

- Utilizes the multifunctional design of the Cylinder Cartridge to allow Torsional testing of a self-supporting rectangular or cylindrical solid sample (e.g. final product)
- Understand how a sample changes by temperature or time in a dry vs. wet environment
- Includes a torsional alignment jig and disposable cylindrical sample end caps
- Mounted samples can be investigated as a function of Frequency, Strain, Stress, Time and Temperature to investigate solid properties
- Easy temperature calibration with sensor mounting provided



Crumb Rubber Kit

- Hard anodized aluminium shallow cup insert for Kinexus cylinder cartridge, designed to measure crumb rubber asphalt mixtures
- Low volume, wide gap concentric cylinder enables samples with larger particles to be measured for more accurate testing
- Optimized thermal properties and mechanical alignment
- Two piece, removable base design, and includes thermal cover and insulation kit

KINEXUS DSR SPECIFICATIONS

A range of asphalt DSR rheometer designed to meet and exceed your application requirements. If you are unsure as to specifying an appropriate rheometer model for your application or region, contact us for advice and/or a demonstration.

	DSR+	DSR	DSR-E	DSR-III
Rheometer specification	Each system designed to meet the demanding needs of research, product development, comparative benchmarking, quality control and assurance required by the global Asphalt / Bitumen Industry			
Motor control	Electronically commutated (EC), drag cup motor control providing absolute direct: shear strain, shear rate, shear stress for operation in steady, dynamic, and transient loading modes			
Torque range – Viscometry (rate and stress control)	5 nNm – 225 mNm	10 nNm – 200 mNm	20 nNm – 200 mNm	100 nNm – 150 mNm
Torque range – Oscillation (strain and stress control)	1 nNm – 225 mNm	5 nNm – 200 mNm	10 nNm – 200 mNm	100 nNm – 150 mNm
Torque resolution	0.1 nNm	0.1 nNm	0.1 nNm	0.1 nNm
Position resolution	<10 nrad	<10 nrad	<10 nrad	<10 nrad
Angular velocity range	1 nrad/s ⁻¹ to 500 rad/s ⁻¹	10 nrad/s ⁻¹ to 325 rad/s ⁻¹	10 nrad/s ⁻¹ to 325 rad/s ⁻¹	10 nrad/s ⁻¹ to 200 rad/s ⁻¹
Step change in strain	<10 ms	<10 ms	<10 ms	<10 ms
Frequency range	6.28 µrad/s ⁻¹ to 942 rad/s ⁻¹ (1 µHz to 150 Hz)	6.28 µrad/s ⁻¹ to 628 rad/s ⁻¹ (1 µHz to 100 Hz)	6.28 µrad/s ⁻¹ to 628 rad/s ⁻¹ (1 µHz to 100 Hz)	6.28 µrad/s ⁻¹ to 628 rad/s ⁻¹ (1 µHz to 100 Hz)
Motor inertia	12 µN.m.s ²	12 µN.m.s ²	13 µN.m.s ²	13 µN.m.s ²
Normal Force range	0.001 N - 50 N	0.001 N - 50 N	0.01 N - 50 N	0.01 N - 20 N
Normal Force resolution	0.5 mN	0.5 mN	0.5 mN	0.5 mN
Normal Force response time	<10 ms	<10 ms	<10 ms	<10 ms
Vertical lift speed	0.1 µms ⁻¹ to 35 mms ⁻¹	0.1 µms ⁻¹ to 35 mms ⁻¹	0.1 µms ⁻¹ to 35 mms ⁻¹	0.1 µms ⁻¹ to 20 mms ⁻¹
Vertical lift range (measurable)	230 mm	230 mm	230 mm	230 mm
Gap resolution (over full vertical lift range)	0.1 µm	0.1 µm	0.1 µm	0.1 µm
Fully configurable vertical profiles	By speed and by Normal Force			
Raw instrument variables	5 kHz constant streaming data			
Complete sample history	Data available from loading to unloading as standard			
Instrument interface	USB2 – plug and play			
Dimensions D x W x H (Weight)	485 mm x 490 mm x 680 mm (47 kg)			
rSpace software	Sequence-driven user interface enabling Standard Operating Procedure (SOP)-type test functionality and fully customizable test designs			
rSpace package	Comprehensive Rheology		Complete Asphalt	Standard Asphalt
User Access Control	✓	✓	✓	✓
General Rheology	✓	✓	✗	✗
rSolution applications database	✓	✓	✗	✗
Rheology Toolkit package	✓	✓	✓	✗
Asphalt Rheology	✓	✓	✓	✓
Rheology Analysis package	✓	✓	✓	✓
Sequence design functionality	✓	✓	✓	✓
Interactive materials database	✓	✓	✓	✓

NOTE: Specifications have been obtained under conditions as stated in the Installation and Site Requirements for Kinexus rheometers

KINEXUS DSR ACCESSORY SPECIFICATIONS

Environmental controllers**	DSR+	DSR	DSR-E	DSR-III
Quick-connect cartridge system	Plug & play; auto-recognition and auto-configuration in software with all alignments and utilities in hardware			
Asphalt Active Hood Oven <ul style="list-style-type: none"> Standard temperature range (optional) Heating rate (controlled) Resolution Stability Gradients 	-5 °C to +200 °C (-40 °C to +200 °C) 30 °C/minute <0.0005 °C +/-0.003 °C <0.1 °C	-5 °C to +200 °C (-40 °C to +200 °C) 30 °C/minute <0.0005 °C +/-0.003 °C <0.1 °C	-5 °C to +150 °C (-40 °C to +200 °C) 30 °C/minute <0.0005 °C +/-0.01 °C <0.1 °C	-5 °C to +150 °C (-40 °C to +200 °C) 30 °C/minute <0.0005 °C +/-0.01 °C <0.1 °C
Universal Cylinder Peltier <ul style="list-style-type: none"> Standard temperature range (optional) Heating rate (controlled) Resolution Stability 	-5 °C to +200 °C (-30 °C to +200 °C) 15 °C/minute <0.0005 °C +/-0.003 °C	-5 °C to +200 °C (-30 °C to +200 °C) 15 °C/minute <0.0005 °C +/-0.003 °C	-5 °C to +150 °C (-30 °C to +200 °C) 15 °C/minute <0.0005 °C +/-0.003 °C	-5 °C to +150 °C (-30 °C to +200 °C) 15 °C/minute <0.0005 °C +/-0.003 °C
High Temperature (HTC) <ul style="list-style-type: none"> Standard temperature range Heating rate (controlled) Resolution Stability 	0 °C to +300 °C 50 °C/minute <0.0005 °C +/-0.003 °C	0 °C to +300 °C 50 °C/minute <0.0005 °C +/-0.003 °C	0 °C to +300 °C 50 °C/minute <0.0005 °C +/-0.003 °C	0 °C to +300 °C 50 °C/minute <0.0005 °C +/-0.003 °C

* Temperature range dependent.

Options Available**		DSR+	DSR	DSR-E	DSR-III
Quick-connect upper geometries	Plug and play; auto-recognition and configuration in software	✓	✓	✓	✓
Disposable plates option	Upper and lower disposable plate options for curing materials	✓	✓	✓	✓
Crumb rubber kit	C14/25 - CRM C25 cup & C14 bob for use with cylinder cartridge. Other cups, bobs and vanes available	✓	✓	✓	✓
Solids Fixtures kit	Solid fixtures for use with cylinder cartridge for testing rectangular or cylindrical solids (Asphalt cores)	✓	✓	✓	✗
Plates and Cones diameter & angle	Standard diameters range from 4 mm to 60 mm Standard angles are 0.5°, 1°, 2° and 4° – others on request	✓	✓	✓	✓
Asphalt Plate diameter	Asphalt 4 mm, 8 mm and 25 mm plates	✓	✓	✓	✓
Tribology - friction	Ball Tribology kit based on ISO7148 design	✓	✓	✓	✗
Temperature Calibration Kit	Fully automated and integrated NIST traceable device for easy verification and calibration of system temperature	✓	✓	✓	✓

NOTE: Specifications have been obtained under conditions as stated in the Installation and Site Requirements for Kinexus rheometers

**Additional Environmental controllers, accessories and geometries available upon request



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