TESTING MATRIX AND PROTOCOLS FOR CALIBRATION OF THE PANDA MODEL

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This document presents the required testing matrix and protocol and apparatus for the calibration of different components of PANDA mechanistic models. Table 1 summarizes the required tests to calibrate the PANDA model. The details on the testing procedure and required equipments is presented in the next section.

Table 1. Required tests for calibration of the PANDA model.

	No. Spec.	*Procedure*	*T(^{o}C)*	*Level*	*LT/RT (sec)**	*Conf. (kPa)*	*Moist. Cond.*	*Aging Cond.*	*Purpose*
Compression	2	TP-62	Varies	50-75 $\mu\varepsilon$	----	0	----	----	VE Calibration
	2	RCRT-VS	55	Varies	0.4/5	140	----	----	VP Calibration
	6	RCRT-CLR	55	840 kPa	0.4/0.4, 1, 5	140	----	----	H-R Calibration
	4	Uniaxial Constant Strain Rate	55	1 strain rate	----	140, 380	----	----	Pressure-sensitivity parameters
Tension	6	Uniaxial Const. Strain Rate	5	3 Rates (1/sec)	----	0	----	----	VD Calibration
	2	RCRT-VRT	19	840 kPa	0.4/Varies	0	----	----	Healing Calibration
	6	TP-62	Varies	50-75 $\mu\varepsilon$	----	0	70-80%-12Hr	----	Moisture Damage Calibration
		TP-62	Varies	50-75 $\mu\varepsilon$	----	0	70-80%-24Hr	----	
		TP-62	Varies	50-75 $\mu\varepsilon$	----	0	50-60%-24Hr	----	
	4	TP-62	Varies	50-75 $\mu\varepsilon$	----	0	----	3 Months	Aging Calibration
		TP-62	Varies	50-75 $\mu\varepsilon$	----	0	----	6 Months	

* LT and RT stand for Loading Time and Resting Time, respectively.

TEST PROTOCOLS

1. Dynamic Modulus Test According to AASHTO TP-62

The dynamic modulus test is used to identify the linear viscoelastic model parameters as well as the temperature coupling term model parameters (i.e. the time-temperature shift factors). This test is conducted at five temperatures (-10, 5, 20, 40, and 55^{o}C) and eight frequencies (0.01, 0.05, 0.1, 0.5, 1, 5, 10, and 25 Hz). The strain amplitude is controlled to be low enough (50-75 $\mu\varepsilon$) such that the material does not get damaged. The AASHTO TP-62 standard can be used to perform this test.

2. Repeated Creep-Recovery Test at Variable Stress Levels (RCRT-VS)

The repeated creep-recovery test at variable stress level (RCRT-VS) at 55^{o}C is used to identify the viscoplastic model parameters. RCRT-VS is a repeated creep-recovery test for which the loading and unloading times remain constant through the entire test (i.e. loading time of 0.4 sec and unloading time of 5 sec). This test consists of several loading blocks. Each loading block consists of eight creep-recovery cycles with increasing applied deviatoric stress level. The deviatoric stress level starts from 140 kPa in the beginning of the first loading block and increases with the factor of 1.2 for the next deviatoric stress level until it reaches the last creep-recovery within that block. For the next loading block, however, the first deviatoric stress level equals to the third stress level in the previous block. Figure 1 schematically shows the applied stress history for the RCRT-VS test.

This test is used to identify the hardening-viscoplastic model parameters as well as the nonlinear viscoelastic model parameters.

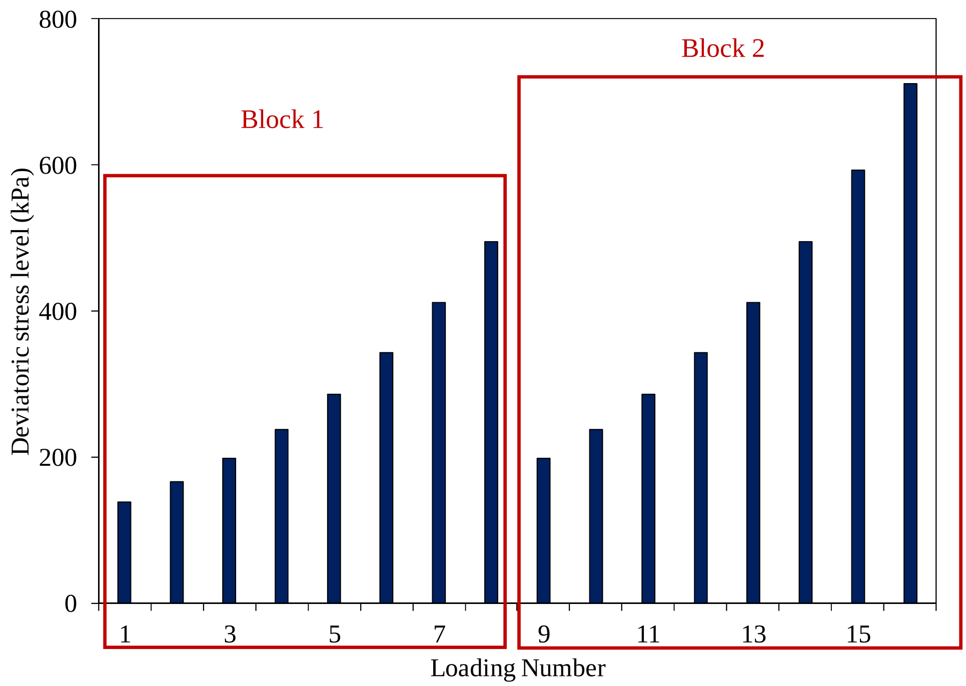

Figure 1. Stress history for the RCRT-VS test.

3. Repeated Creep-Recovery Test at Constant Loading and Rest Times (RCRT-CLR)

The RCRT-CLR test consists of blocks of repeated creep-recovery tests with the rest periods between the loading cycles. The applied deviatoric and confinement stress for RCRT-CLR tests are 840kPa and 140kPa, respectively. The loading time and the rest periods between the loading cycles within each loading block are kept constant. RCRT-CLR tests at different resting periods of 0.1, 1, and 5 sec are used to identify the hardening-relaxation model parameters. The stress history for the RCRT-CLR test is schematically presented in Figure 2.

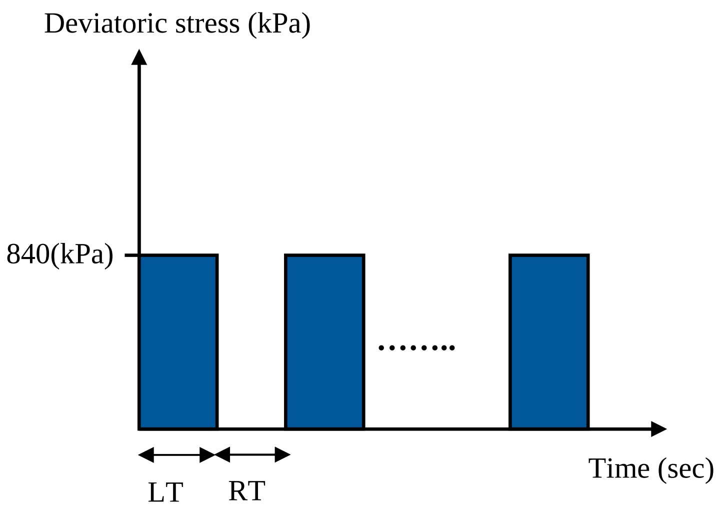

Figure 2. Schematic representation of the stress input for RCRT-CLR test. Both loading time (LT) and resting time (RT) are constant through the entire test.

4. Repeated Creep-Recovery Test at Variable Resting Time (RCRT-VRT)

The RCRT-VRT test consists of blocks of repeated creep-recovery tests with the rest periods between the loading cycles. The applied stress level and loading time (i.e. 0.4 sec) remain constant throughout the RCRT-VRT test. However, the resting time starts at 0.9 sec and increases by a ratio of $1.2^{(n-1)}$, where n is the number of loading cycles. When the rest period becomes too long (i.e. longer than 30 sec), the rest period will be reset to 0.9 sec and the block of the repeated creep-recovery test will be repeated. This test will be used to identify the micro-damage healing model parameters. The stress history for the RCRT-VRT test is schematically presented in Figure 3.

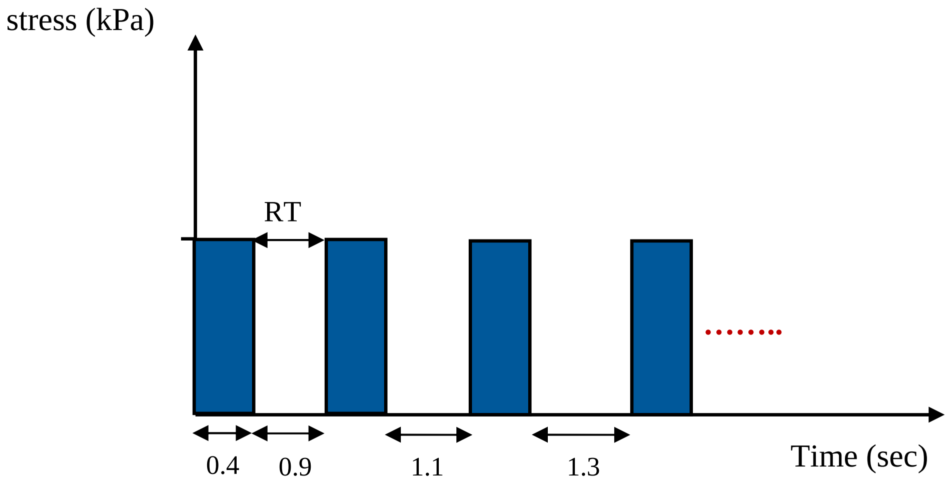

Figure 3. Schematic representation of the stress input for RCRT-VRT test. Loading time (LT) remains constant through the entire test where the resting time (RT) changes for each loading cycle.

5. Dynamic Modulus Test for Moisture Conditioned Specimens

The modified Lottman procedure without the freeze-thaw cycles is used for moisture conditioning. The specimens are put in the vacuum vessel until the level of saturation reaches 70-80%. The saturated specimens will then be conditioned in a water bath at the temperature of 55^{o}C. Two conditioning times of 12 hours and 24 hours are used for this test. The dynamic modulus test is then performed on the conditioned specimens according to AASHTO TP-62. The details for the specimen conditioning as well as the testing procedure on the moisture-conditioned specimens are still in the development stage.

2. Apparatus

6.1 *Materials Testing System (MTS):* The machine should be capable of producing controlled load in both tension and compression. The MTS shall be equipped with ±5,000 lb load cell. The system should be capable of applying load over a range of frequencies (0.1 to 25 Hz), and a confining pressure up to 400 kPa (air). The system shall be fully computer controlled capable of measuring and recording the time, load, deformation, and confining pressure. Figure 4 shows the MTS at TTI.

6.2 *Environmental Chamber*: The chamber is required to control the temperature of the test specimens at the desired temperatures. The environmental chamber should be capable of controlling the temperature of the test specimens over a temperature range of -10 to 55^{o}C. The chamber should be big enough to accommodate the triaxial cell (Figure 5).

6.3 *Triaxial Cell*: A triaxial is required for applying a confining pressure on the test specimens. The cell should stand a working pressure up to 400 kPa (air). The cell should be big enough to accommodate the test specimens (101.6 mm diameter by 152.4 mm height). The cell shall facilitates up to three “through the wall” radial strain transducers. Figure 5 shows a triaxial at TTI.

6.4 S*train Transducers*: The axial and radial deformation shall be measured using linear variable differential transformers (LVDT). Three axial LVDTs shall be used measure the axial deformation. The axial LVDT should be mounted between gauge points glued on the specimens. The LVDTs shall be placed at 120° around the circumference of the test specimen. The gauge length between the axial LVDT holders should be 101.6 mm. A schematic view of the test setup with mounted axial LVDTs is given in Figure 6. Three radial LVDTs shall be used to measured the radial deformation at the middle of the test specimens. Figure 5 shows a tri-axial with “through the wall” radial LVDTs.

Figure 4. MTS System at TTI.
(Left: Environmental Chamber; Right: Measuring system)

Figure 5. Tri-axial Cell inside Environmental Chamber.

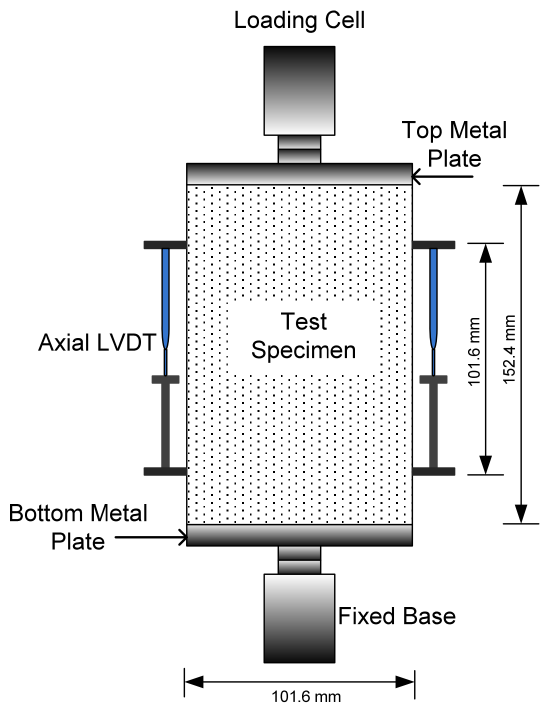

Figure 6. Schematic view of test setup with Mounted Axial LVDTs.