Continuum Model Validation

ARC

Federal Highway Administration Expert Task Group Meeting

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Core Materials

Core Aggregates for ARC

Aggregate ID	Description	Source
ARC-AG-001	Siliceous Conglomerate	WY
ARC-AG-002	Hanson Limestone	TX
ARC-AG-003	Andesite	NV
ARC-AG-004	Limestone	WI
ARC-AG-005	Watsonville Granite from the Granite Rock Company in California	CA
ARC-AG-006	Gravel	AR, also used in TX

Note: the ARC AG 001 and ARC AG 002 are the main core aggregates. All the remaining core aggregates are for supplement studies.

Core Binders for ARC

Binder ID	Supplier	Reported Crude Source	Location
ARC-BI -001	NuStar Energy	Paulsboro, NJ	Venezuelan
ARC-BI-002	Montana Refining OR Exxon-Mobil*	Great Falls, MT OR Billings, MT	W. Canadian blend
ARC-BI-003	Valero Refining	Benicia, CA	CA Valley & ANS
ARC-BI-004	W.Texas Intermediate OR Saudi Arabian Medium/Heavy OR Gulf Coast*	Valero Refining OR another source	To be decided

*WRI to pick one from the possible alternatives in this row

Binder-Aggregate Combinations of Test Mixtures

Binders	Aggregates	Mastic and Fine Asphalt Mixtures	Full Asphalt Mixtures
ARC-BI-001	ARC-AG-001	X	X
	ARC-AG-002	X	X
ARC-BI-002	ARC-AG-001	X	
	ARC-AG-002	X	X
ARC-BI-003	ARC-AG-001	X	
	ARC-AG-002	X	

Validation of CDM

- Approach 1
  - Obtain model parameters for test sets (triaxial at different strain rates, creep-recovery tests)
  - Use model to predict responses of mixtures under different, more complex lab loading conditions (random frequency, random load levels)
- Approach 2
  - Compare against bench scale experiments to verify correct model has attributes and features to reflect mixture response (hardening, damage, damage, healing, aging, etc,)

Extracted from "Validation of ARC Models and Test Methods, April, 2009

Work Element	Examples of Models/Tests	Examples of Test Methods to Obtain Input Parameters	Examples of Parameters Obtained	Examples of Application	Validation
F2e, F3c, and M4c	Viscoelastic Continuum Damage Model	Triaxial extension and compression	• Mixture hardening • Plastic damage evolution • Yield surface parameters	Predict asphalt mixture behavior under various lab and field conditions	• Nottingham database • ALF experiments • Westrack • Lab ALTs

Nottingham Experimental Measurements

- Two Asphalt Mixtures;
  - Aggregate: Granite
  - Binder: 70/100 penetration
  - Mixtures:
    - Dense Bitumen Macadam (DBM), Dense graded mixtures
    - Hot Rolled Asphalt (HRA), gap graded mixtures
- Data base: uniaxial and triaxial tests with compression and tension loading conditions; different temperature and stress levels
- Wheel tracking Data: small scale wheel tracking, large scale wheel tracking and full scale wheel tracking

University of Nottingham Database of Compression Tests

Mixture Type: DBM					
Temp.	Repeated loading	Triaxial	Creep recovery	Constant load	Constant strain rate
10			Stress=2000,2500	Stress=2000,2500	Strain rate= 0.00005, 0.0005, 0.005
20	Stress=1500 (Loading Time=60 sec with Rest time=50,100,1500 sec Loading Time =1200 with Rest time= 1500)		Stress=1000,1500, 2000	Stress=1000,1500, 2000	Strain rate= 0.00005, 0.0005, 0.005
35		Axial stress=500,750, 1000,1500 with stress ratio=0.33,0.56, 0.462			
40			Stress=500,750	Stress=500,750	Strain rate= 0.0005, 0.005
Mixture Type: HRA					
10			Stress=1500,2000	Stress=1500,2000	Strain rate= 0.00005, 0.0005, 0.005
20	Stress=1000 (Loading Time=30 sec with Rest time=50,100,1500 sec Loading Time =60 with Rest time= 1500)		Stress=1000,1500, 2000	Stress=1000,1500, 2000	Strain rate= 0.00005, 0.0005, 0.005
35		Axial stress=300,500, 700 with stress ratio=0.33,0.7, 0.562			
40			Stress=400,500	Stress=400,500	Strain rate= 0.0005, 0.005

Note: Stress in kPa

University of Nottingham Database of Tension Tests

Note: Stress in kPa

Mixture Type: DBM				
Temp.	Repeated loading	Creep recovery	Constant load	Constant strain rate
5				
10			Stress=500,1000,1500	
20	Stress=300 (Loading Time=60 sec with Rest time=50,100,1500 sec Loading Time =120 with Rest time= 100)	Stress=100	Stress=100,300, 500,700	Strain rate=0.00167,0.0167
35			Stress=50,100, 150	
Mixture Type: HRA				
5		Stress=1500	Stress=1000,1500	
10			Stress=300,500, 1000	
20	Stress=200 (Loading Time=30 sec with Rest time=50,100,1500 sec Loading Time =60 with Rest time= 50) Stress=300 (Loading Time=30 sec with Rest time=50,100 sec Loading Time =60 with Rest time= 50)	Stress=100	Stress=100,200, 300,500	
35			Stress=50,75,100	

University of Nottingham Database of Wheel Tracking Tests

Mixture Type: DBM			
Temperature	Small Scale Wheel Tracking	Large Scale Wheel Tracking	Full Scale Wheel Tracking
35	Stress= 540, 770	Stress=510	Stress= 675,740,885,1000
Mixture Type: HRA			
20	Stress= 540,770		
35	Stress= 540, 770	Stress=510	Stress= 675,740,885,1000

Testing Materials - NCSU Experiments

Relevant Asphalt Binder Information

Binder	Designation	PG Grade	Cont. PG Grade
Unmodified	Control/Control-2006	70-22	72-23
Crumb Rubber Term. Blend	CR-TB	76-28	79-28
Styrene-Butadiene-Styrene	SBS	70-28	74-28
Ethylene Terpolymer	Terpolymer	70-28	74-31

Summary of Air void Content and Binder Content for NCSU Experiments and ALF Lanes

Mixture	Laboratory		Test Lanes		
	% Air Voids	% Asphalt[1]	% Air Voids	% Asphalt[1] Ignition	% Asphalt[1] Nuclear
Control	4.0	5.3	7.8	5.23	4.82
CRTB			6.8	5.48	5.09
SBS			6.0	5.28	5.05
Terpolymer			6.5	5.52	5.25

[1] by percent mass

Source: MVEPCD Report Final 508-8-31-08

Testing Protocols - NCSU Experiments

- Complex Modulus Test
- Constant Crosshead Rate Tests
- Repetitive Creep and Recovery Tests
  - Variable Load (VL) Test
  - Variable Time (VT) and Reversed Variable Time (RVT) Test
  - Constant Load and Time (CLT) Test
  - Variable Load and Time (VLT) Test

Source: MVEPCD Report Final 508-8-31-08

Testing Protocols - NCSU Experiments

Controlled Crosshead Testing Matrix in Tension

Test ID	Confining Pressure (kPa)		Temp. (°C)	Crosshead Strain Rate	Purpose
	0	500			
5-1-T	X	X	5	5.50E-05	MVECD Characterization
5-2-T	X	X		3.00E-05	
5-3-T	X	X		2.20E-05	
5-4-T		X		2.15E-05	
5-5-T		X		1.50E-05	
5-6-T	X			1.05E-05	MVEPCD and t-TS Verification
25-1-T		X	25	5.00E-04	
25-2-T		X		1.50E-03	
25-3-T		X		4.50E-03	
25-4-T		X		1.35E-02	
40-1-T	X	X	40	3.00E-02	
40-2-T	X	X		1.00E-02	VP Characterization
40-3-T	X	X		3.00E-03	
40-4-T	X	X		1.00E-03	
40-5-T	X	X		3.00E-04	

Source: MVEPCD Report Final 508-8-31-08

Testing Protocols - NCSU Experiments

Creep and Recovery Testing Matrix in Compression

		Confining Pressure (kPa)		
		0	140	500
VT		X	X	X
RVT			X	X
VL		X	X	X
VLT			X	X
CLT	0.4s			X
	1.6s			X
	6.4s			X
VT + Flow Number			X	

- The ALF experiment of the FHWA

Source: MVEPCD Report Final 508-8-31-08

Testing Protocols - NCSU Experiments

Controlled Crosshead Testing Matrix in Compression

Test ID	Confining Pressure (kPa)		Temp. (°C)	Crosshead Strain Rate	Purpose
	0	500			
5-1	X	X	5	5.75E-05	MVECD Characterization
5-2	X	X		3.83E-05	
5-3	X	X		1.92E-05	
5-4	X	X		9.60E-06	
25-1	X	X	25	1.35E-02	t-TS Verification
25-2	X	X		4.50E-03	
25-3	X	X		1.50E-03	
25-4	X	X		5.00E-04	
40-1	X	X	40	3.01E-02	
40-2	X	X		1.00E-02	
40-3	X	X		3.00E-03	
40-4	X	X		1.00E-03	
55-1	X	X	55	2.99E-02	
55-2	X	X		1.00E-02	
55-3	X			3.00E-03	
55-4	X			1.00E-03	

Source: MVEPCD Report Final 508-8-31-08

Westrack Test Sections

- Experimental Factors
  - Aggregate Type: (local Dayton, Nevada pit)
  - Aggregate Gradation (Coarse, fine, and fine plus)
  - Asphalt Binder: PG 64-22
  - Binder Content (4.7, 5.4 and 6.1 for the fine mixes; 5.0, 5.7 and 6.4 for the coarse mixes)
  - Air Void Content (4, 8 and 12 percent)

Westrack Test Sections

Original 1995 Construction										1997 Rehabilitation	
Design Air Void Content %	Aggregate Gradation Design										
	Fine			Fine Plus			Coarse			Coarse	
	Design Asphalt Contents (%)										
	4.7	5.4	6.1	4.7	5.4	6.1	5.0	5.7	6.4	5.1	5.8	6.5
4		4	18		12	21/9		23	25		39	55
8	2	1/15	14	22	19/11	13	8	5/24	7	38	35/54	37
12	3/16	17		10	20		26	6		56	36	

Numbers shown in each cell represent actual test section numbers,
Note: Six cells were eliminated due to the construction impracticality

Source: http://www.westrack.com/wt_02.htm