WORKSHOP
on
Rheology and 3D Printing of Concrete

August 5 – 7, 2024 | Missouri S&T, Rolla, MO

DuRe-Transp
Tier 1 University Transportation Center for Durable and Resilient Transportation Infrastructure

NSF AccelNet: 3D Concrete Printing Network (3DConcrete) - Accelerating Progress in Concrete Additive Manufacturing

Contents

Main Topic

Rheology and HPC with Adapted Rheology

1. General Rheology and Models
2. Influence of Constituent on Rheology of Cement-Based Materials
3. Links Between Rheology and Workability
4. Rheology of SCC and Underwater Concrete
5. Factors Affecting Thixotropy of Cement-Based Materials
6. Rheology and Early-Age Hydration of 3DPC

3D Printing Concrete Technology

1. Printing Parameters of 3DCP, Architecture/Printing Path
2. Test Methods for Evaluating 3DCP Performance: In-line, Off-line
3. 3DCP Ink Mixture Design, Binder Systems, Chemical Admixtures, Nano Materials, and Fibers for 3DPC
4. Hardened Properties of 3DPC, Comparison Between Cut vs. Mold Samples, Anisotropy
5. Emerging Properties, Motivation for Architected/Bioinspired Material Design
6. 3D Printed Concrete: From Conception to Prototype (Case study)

Workshop Chair

Kamal H. Khayat
Missouri University of Science and Technology

Dr. Kamal Khayat, the Vernon and Maralee Jones Professor of Civil Engineering at Missouri S&T, has served as vice chancellor for research and innovation since 2021. He is the associate director of DuRe-Transp UTC and was the director of the Center for Infrastructure Engineering Studies, the Center for Research on Concrete Applications for Sustainable Transportation, and the Center for Transportation Infrastructure and Safety. Before joining Missouri S&T, Dr. Khayat was the director of the Center of Excellence on Concrete Infrastructure Engineering and head of the Integrated Research Laboratory at the Université de Sherbrooke in Canada. His main research interests are the design of innovative structural materials, including high-performance concrete with adapted rheology. Dr. Khayat has authored and co-authored over 530 publications and has advised 46 Ph.D. students, 45 master's students, as well as 22 post-doctoral fellows and visiting scholars.

Jan Olek
Purdue University

Dr. Jan Olek is a James H. and Carol H. Cure Professor of Civil Engineering in the Lyles School of Civil Engineering at Purdue University where he also serves as the Director of the North Central Superpave Center and the Director of Pankow Materials Laboratory. He has conducted research on multiple projects related to such topics as concrete technology, supplementary cementitious materials, durability of construction materials and structures, Superpave technology, tire-pavement noise mitigation, nanotechnology, and 3D-printing of cementitious materials. Dr. Olek's work has been supported, among others, by INDOT, FHWA, NCHRP, NSF, PCA and private industry. He is an author and the co-author of over 200 technical papers, the Fellow of the ACI, and the recipient of the ACI's Robert E. Philleo Research Award. He is the chair of the ACI committee 552 on cementitious grouting and an active member of several technical committees of the ACI and the TRB.

Organizing Committee

Chairs

Kamal H. Khayat, Missouri University of Science and Technology, USA

Jan Olek, Purdue University, USA

Members

Pable D. Zavattieri, Purdue University, USA

Jaffrey Youngblood, Purdue University, USA

Yu Wang, Purdue University, USA

Donna Luechtefeld, Missouri University of Science and Technology, USA

Gayle Spitzmiller, Missouri University of Science and Technology, USA

Jason Cox, Missouri University of Science and Technology, USA

Seongho Han, Missouri University of Science and Technology, USA

Yucun Gu, Missouri University of Science and Technology, USA

Panagiotis Danoglidis, University of Texas at Arlington, USA

Workshop Program

Floating Trip (Optional)			
Day 0, Sunday, August 4,			
9:00 – 17:00			

Rheology and HPC with Adapted Rheology			
Day 1, Monday, August 5		**Location**	**Presenter**
7:30 – 8:15	Registration & Coffee	Innovation Lab – Atrium	
8:15 – 8:30	Opening Remarks		Kamal Khayat /Jan Olek
8:30 – 9:15	General Rheology and Models	Forum Room	Jeffrey Youngblood
9:15 – 10:30	1. Influence of Constituent on Rheology of Cement-Based Materials 2. Links Between Rheology and Workability	Forum Room	Kamal Khayat
10:30 – 10:45	Coffee Break	Atrium	
10:45 – 12:15	1. Rheology of SCC and Underwater Concrete 2. Factors Affecting Thixotropy of Cement-Based Materials	Forum Room	Kamal Khayat
12:15 – 13:45	Lunch / Poster Session / Case Study	Atrium/Forum Room	Pablo Zavattieri
13:45 – 14:30	Rheology and Early-Age Hydration of 3DPC	Forum Room	Narayanan Neithalath
14:30 – 15:15	Printing Parameters of 3DCP, Architecture/Printing Path	Forum Room	Yu Wang
15:15 – 15:30	Move to Clayco ACML		
15:30 – 17:30	Lab Visits and Demonstrations of Rheology and Test Methods to Evaluate 3DCP	ACML	Kamal Khayat
18:00 –	Dinner		

3DP Concrete Technology

Day 2, Tuesday, August 6		Location	Presenter
8:00 – 9:00	Test Methods for Evaluating 3DCP Performance: In-line, Off-line	Forum Room	Yucun Gu /Seongho Han
9:00 – 10:15	3DCP Ink Mixture Design, Binder Systems, Chemical Admixtures, Nano Materials, and Fibers	Forum Room	Jan Olek /Jeffrey Youngblood
10:15 – 11:30	1. Hardened Properties of 3DPC, Comparison Between Cut vs. Mold Samples, Anisotropy 2. Emerging Properties, Motivation for Architected/Bioinspired Material Design	Forum Room	Yu Wang /Pablo Zavattieri
11:30 – 13:00	Lunch / Poster Session II / Industrial Presentation	Atrium	Pablo Zavattieri
13:00 – 13:30	Introduction to Breakout Sessions	Forum Room	Pablo Zavattieri
13:30 – 15:30	Breakout Sessions	Room 212 Room 213	Pablo Zavattieri
15:30 – 15:45	Coffee Break	Atrium	
15:45 – 17:45	3D Printed Concrete: From Conception to Prototype (Case study)	Forum Room	Szymon Skibicki
18:15 –	Dinner		

3DP Concrete Technology

Day 3, Wednesday, August 7		Location	Presenter
8:00 – 8:15	Introduction to Groups and their Topics	Room 115	Pablo Zavattieri
8:15 – 10:30	Group Leaders to Present their Respective Topics/Discussions/Main Ideas	Room 115	Pablo Zavattieri
10:30 – 10:45	Coffee Break	Atrium	
10:45 – 11:45	Presentation of DuRe-Transp and AcclNet	Room 115	Panagiotis Danoglidis /Jan Olek
11:45 – 12:00	Closing Remarks		Kamal Khayat /Jan Olek
12:00 – 13:00	Lunch		

Poster Session

Poster dimensions: 30" x 40" portrait or landscape

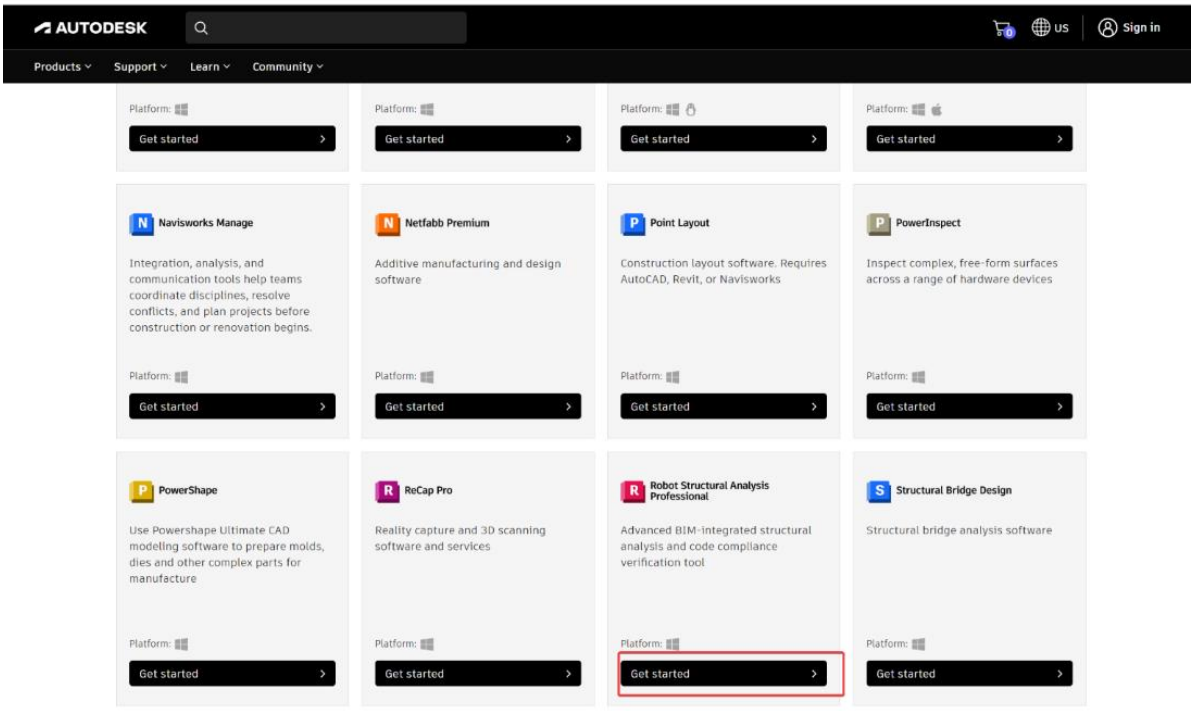
Topics: Related to Workshop such as 3D concrete printing technology, Rheology, and HPC with adapted rheology

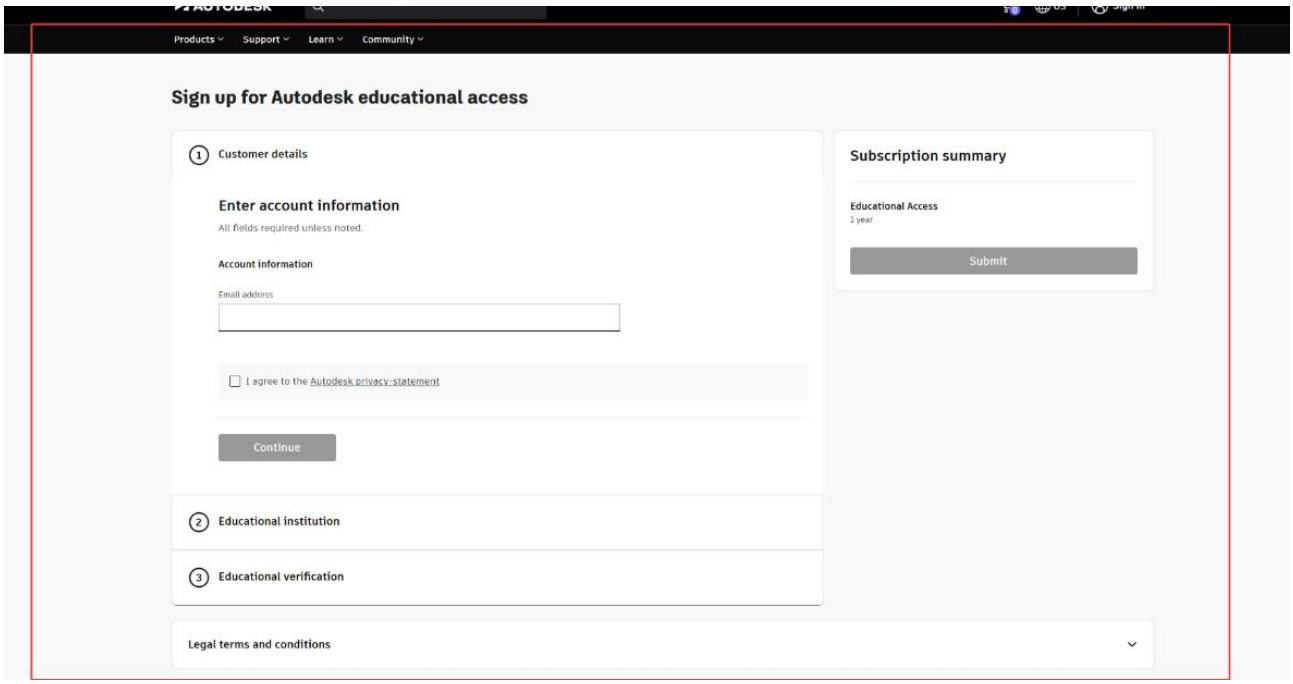
Wi-Fi

All non-campus affiliated participants should use the guest Wi-Fi while on campus.
Go to Link https://it.mst.edu/services/wireless/guest/
Follow the steps that belong to the device the user would like to connect to the Wi-Fi.
Please note that different procedures are required for different brands

Software

You will need the *Robot Structural Analysis Professional from Autodesk* for Day 2 lecture titled '3D Printed Concrete: From Conception to Prototype (Case study)' presented by Dr. Szymon Skibicki. Link to Autodesk software is shown below along with the illustration of which program to get and how to establish the educational account https://www.autodesk.com/education/edu-software/





Floating Trip

We will gather together in the parking lot at the Engineering Research Lab (ERL) Building at Missouri S&T (Engineering Research Lab, Rolla, MO 65409).
Here is the location on Google Maps: ERL Building.

We plan to leave around 9 am, though this time is subject to change. Updates will be sent via email.

If you are late or have any other concerns, please contact Jason Cox at 573-578-0123 and Seongho Han at 573-537-0882.

Floating trip location: Bird's Nest Lodge Steelville Mo

Rental Option (Price):

(1) 2-person for canoe ($50 split in half)
(2) Single person for kayak ($40)

You must bring **cash** for direct payment.

Alternative Option (if Rainy weather)

Onondaga Cave tours

Address: 7556 Missouri H, Leasburg, MO 65535

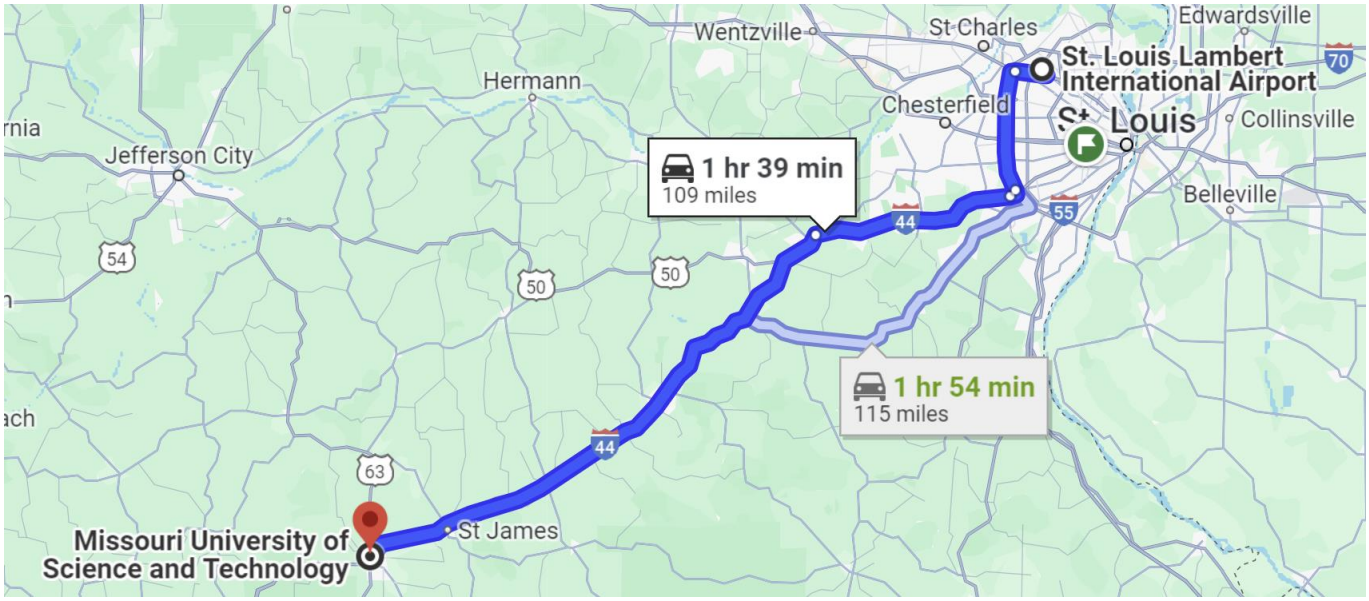
Tours can be reserved online on our reservation website or by visiting the park. For more information, contact the park at 573-245-6576

Tour admission fees vary depending on age, from free to $18.00. Trained guides will lead you over electrically lighted paved walkways and provide information about geologic wonders such as the King's Canopy, the Twins, and other unusual speleothems. With an interesting history and a river flowing through the cave, Onondaga Cave is a spectacular registered National Natural Landmark. Onondaga Cave tours leave from the visitor center. They are walking tours, just less than 1 mile long, and last about one hour and 15 minutes. The cave's temperature is 57ºF (13ºC) year-round, so bring a jacket and comfortable shoes. Contact the park for additional tour availability. Please arrive ten minutes before the tour start time.

FEES

REGULAR ADMISSION	
Adult (ages 18-64)	$12
Teenager (ages 13-17)	$10
Child (ages 6-12)	$8
Child (under age 6)	Free
Military	$10
Senior (ages 65 and up)	$10
ONONDAGA AND CATHEDRAL CAVES COMBO PRICING (Both tours must be taken the same day. Please note when planning your visit that Cathedral Cave tours are offered only at certain times. **Sorry, there are no refunds on combo tickets.**)	
Adult (ages 13-64)	$25
Child (ages 6-12)	$14
Child (under age 6)	Free
Military	$23
Senior (ages 65 and up)	$23

Traveling to Rolla



Tips for traveling to Rolla:

Best option: Fly into St-Louis Lambert Airport (STL) and rent a car (1 h 45 min drive). An airport shuttle from STL is available (https://usaxonline.com/), but this limits your mobility in Rolla. Taxis and rideshares are very limited in Rolla. Please plan on renting a car for easy mobility.

Secondary option: Fly into Springfield-Branson (SGF) airport and rent a car (also 1h 45 min drive).

Third option: Fly into Columbia regional airport (COU) and rent a car. More limited options are available.

Accommodation

Hampton Inn
Reservation Deadline: July 15, 2024
Address: 2201 N Bishop Ave, Rolla, MO 65401
Phone: (573) 308-1060
How to make reservation: Call hotel directly
Group: Dura-Transp
Group Code: DTG
20 double queens available in this group
Cost: $149/night, expires on July 15, 2024.

Comfort Suites
Reservation Deadline: July 31, 2024
Address: 1650 Old Wire Outer Rd, Rolla, MO 65401
Phone: (573) 677-4004
How to make reservation: Call hotel directly or use the Hyperlink
Cost: King Suites: $115 for two people, $10/per each additional person
Queen Suite: $122 for two people, $10/per each additional person
4 King suites available for August 3 and an additional 11 suites available August 4
5 Queen suites available August 3 and an additional 10 suites available August 4

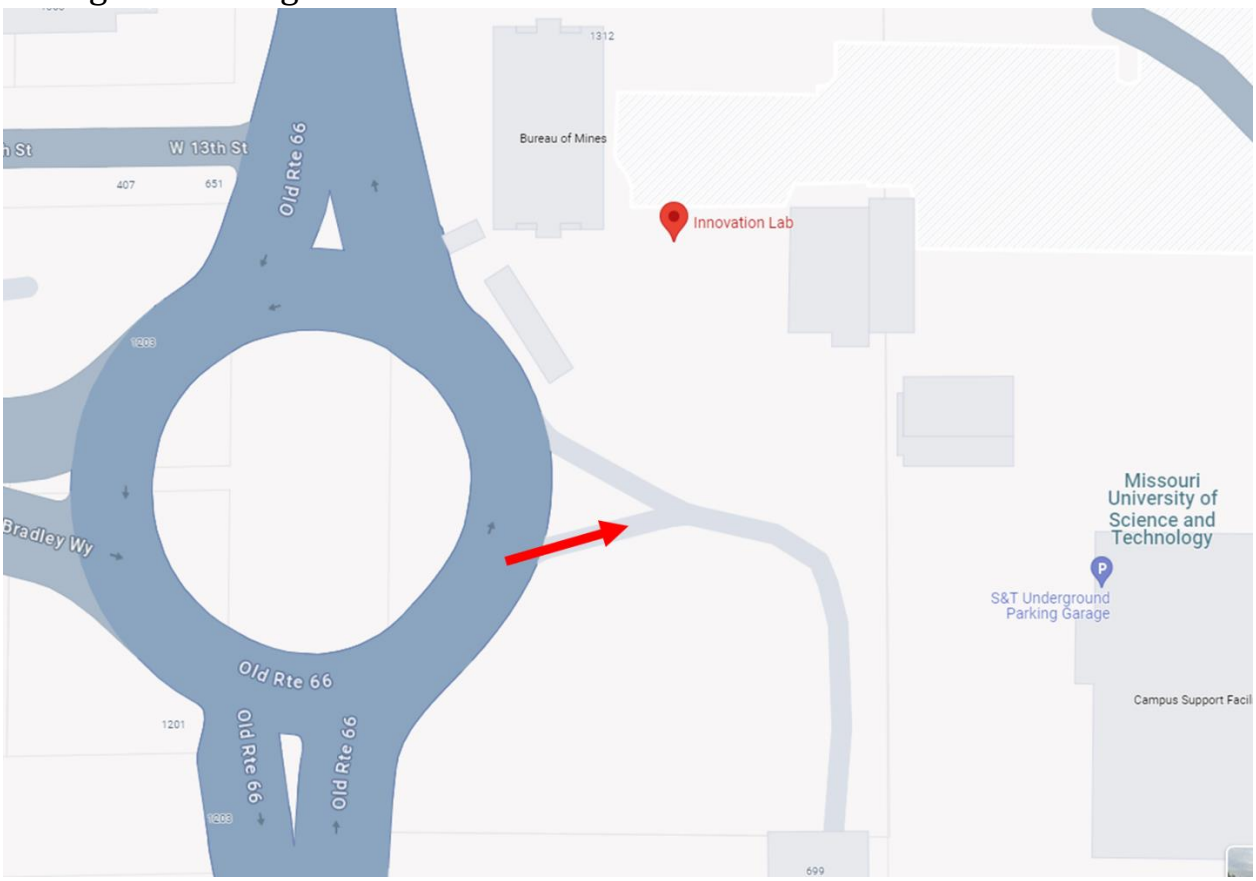
Location/Parking

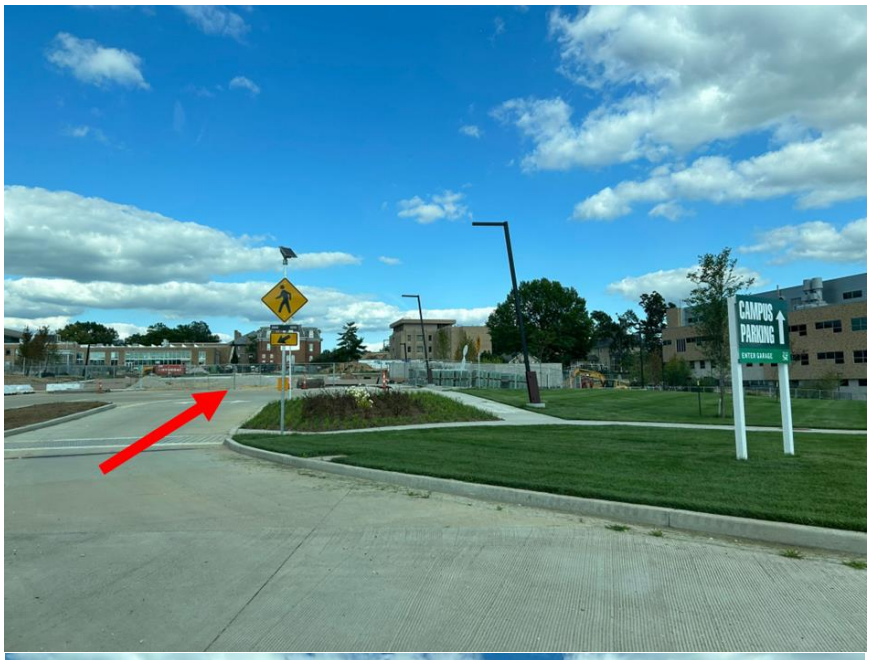
Innovation Lab (#52 building, Campus Map)

650 Tim Bradley Wy, Rolla, MO 65401 https://masterplan.mst.edu/innovationlab/

Parking information of Innovation Lab:
If you need parking pass, please contact Seongho Han (shhan@mst.edu) or Donna Luechtefeld (dsl5z6@mst.edu)

How to go to Parking lots:

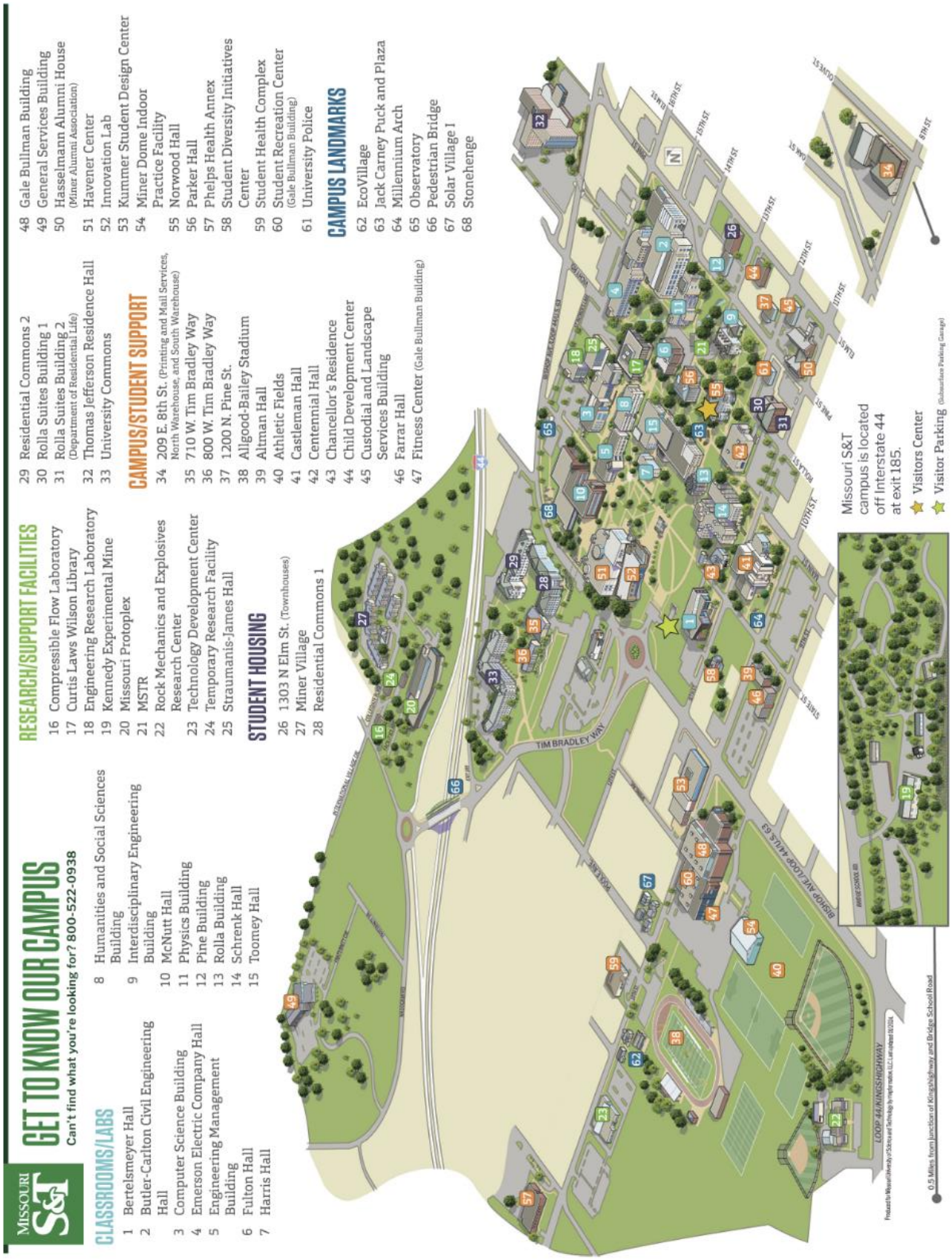



CAMPUS
PARKING

ACML (#2 building, Campus Map)

1401 N Pine St, Rolla, MO 65409

Campus Map


MISSOURI S&T
GET TO KNOW OUR CAMPUS
Can't find what you're looking for? 800-522-0938
CLASSROOMS/LABS
1 Bertelsmeyer Hall
2 Butler-Carlton Civil Engineering Hall
3 Computer Science Building
4 Emerson Electric Company Hall
5 Engineering Management Building
6 Fulton Hall
7 Harris Hall
8 Humanities and Social Sciences Building
9 Interdisciplinary Engineering Building
10 McNutt Hall
11 Physics Building
12 Pine Building
13 Rolla Building
14 Schrenk Hall
15 Toomey Hall
RESEARCH/SUPPORT FACILITIES
16 Compressible Flow Laboratory
17 Curtis Laws Wilson Library
18 Engineering Research Laboratory
19 Kennedy Experimental Mine
20 Missouri Protoplex
21 MSTR
22 Rock Mechanics and Explosives Research Center
23 Technology Development Center
24 Temporary Research Facility
25 Straumanis-James Hall
STUDENT HOUSING
26 1303 N Elm St. (Townhouses)
27 Miner Village
28 Residential Commons 1
29 Residential Commons 2
30 Rolla Suites Building 1
31 Rolla Suites Building 2 (Department of Residential Life)
32 Thomas Jefferson Residence Hall
33 University Commons
CAMPUS/STUDENT SUPPORT
34 209 E. 8th St. (Printing and Mail Services, North Warehouse, and South Warehouse)
35 710 W. Tim Bradley Way
36 800 W. Tim Bradley Way
37 1200 N. Pine St.
38 Allgood-Bailey Stadium
39 Altman Hall
40 Athletic Fields
41 Castleman Hall
42 Centennial Hall
43 Chancellor's Residence
44 Child Development Center
45 Custodial and Landscape Services Building
46 Farrar Hall
47 Fitness Center (Gale Bullman Building)
48 Gale Bullman Building
49 General Services Building
50 Hasselmann Alumni House (Miner Alumni Association)
51 Havener Center
52 Innovation Lab
53 Kummer Student Design Center
54 Miner Dome Indoor Practice Facility
55 Norwood Hall
56 Parker Hall
57 Phelps Health Annex
58 Student Diversity Initiatives Center
59 Student Health Complex
60 Student Recreation Center (Gale Bullman Building)
61 University Police
CAMPUS LANDMARKS
62 EcoVillage
63 Jack Carney Puck and Plaza
64 Millennium Arch
65 Observatory
66 Pedestrian Bridge
67 Solar Village 1
68 Stonehenge
TIM BRADLEY WAY
BISHOP AVE LOOP A MILS 63
LOOP 44/KINGS HIGHWAY
Missouri S&T campus is located off Interstate 44 at exit 185.
Visitors Center
Visitor Parking (Subsurface Parking Garage)
0.5 Miles from Junction of Kings Highway and Bridge School Road

Workshop Contact

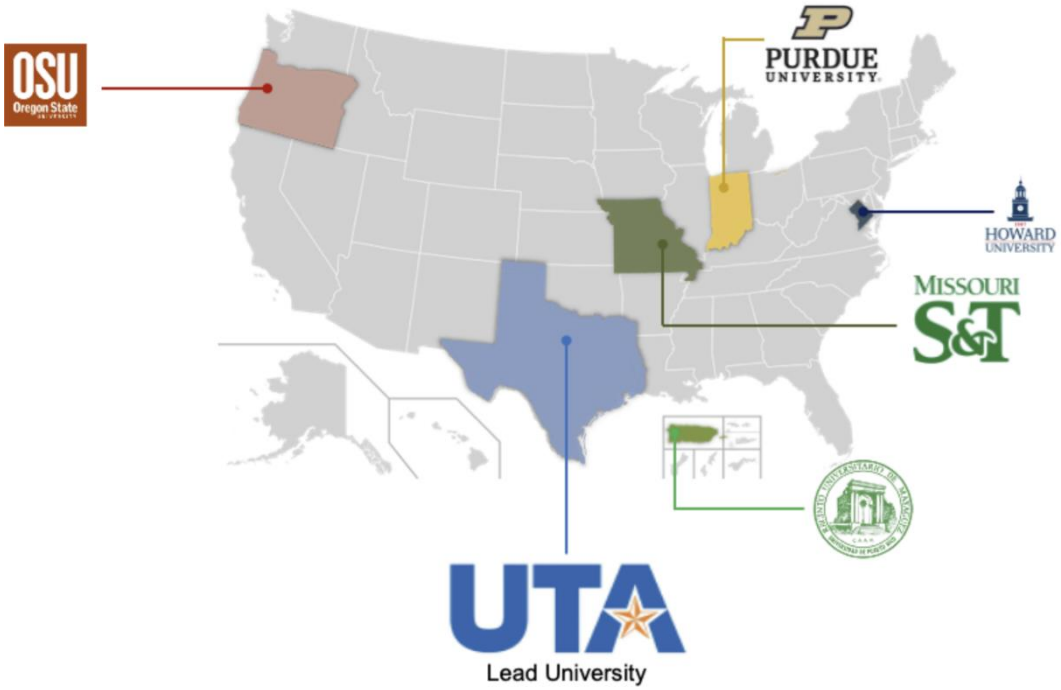
Workshop Contact	Yucun Gu Seongho Han	gywvy@mst.edu shhan@mst.edu
Floating Trip	Yucun Gu Jason cox	gywvy@mst.edu coxjn@mst.edu
Registration, Payment, Invoices	Gayle Spitzmiller	spitz@mst.edu
Workshop Venue, Presentations	Donna Luechtefeld Seongho Han	dsl5z6@mst.edu shhan@mst.edu
Transportation, Catering, Accommodation	Donna Luechtefeld Yucun Gu	dsl5z6@mst.edu gywvy@mst.edu
Lab Visits and Demonstration	Jason Cox Yucun Gu	coxjn@mst.edu gywvy@mst.edu

DuRe-Transp

The Center for Durable and Resilient Transportation Infrastructure focuses on the statutory research priority area "Improving the durability and extending the life of transportation infrastructure".

The consortium driving the Center's mission is comprised of a transdisciplinary team of prominent researchers from six U.S. universities:

- The University of Texas at Arlington (UTA, Lead);
- Howard University (HU);
- Missouri University of Science and Technology (S&T);
- Oregon State University (OSU);
- Purdue University (PU), and
- the University of Puerto Rico – Mayagüez (UPRM).



By leveraging such collaboration, the Center will address critical areas of national importance in the strategic topics of Durability, Construction, and Finance, focusing on the following Research Themes:

Durability
Research Theme I: Inspection, Maintenance and Preservation (IMP)
Research Theme II: Sustainability and Longevity (SL)
Research Theme III: Health Monitoring (HM)

Construction
Research Theme IV: Sustainable Materials and Structures for Climate Change Mitigation (CCM)
Research Theme V: Advanced Materials and Technologies for Construction and Retrofit (CR)
Research Theme VI: Construction Methods and Management (CMM)

Finance
Research Theme VII: Innovative Revenue and Finance (RF)

Address: Nedderman Hall, Suite 300
416 Yates St, Arlington, Tx 76010
Phone: 817-272-2639
Email: duretransp-uta@uta.edu
Website: https://duretransp.uta.edu/

Missouri University of Science and Technology

Founded in 1870 as a product of the land-grant movement during the height of the Industrial Revolution, our university - then known as the Missouri School of Mines and Metallurgy, or MSM - was Missouri's response to the acute need for scientific and practical education in the developing nation. Early academic programs focused on the mining and metallurgical industries, but the campus expanded its mission over time as the need for a broad-based education grew.

In 1964, the four-campus University of Missouri System was established, and our campus became known as the University of Missouri-Rolla or UMR. In 2008, the name was changed to Missouri University of Science and Technology, or informally as Missouri S&T, to reflect our distinctive nature as a national research university.

Today, Missouri S&T is in its second 150 years building upon its heritage of discovery, creativity and innovation to inspire and prepare students of all majors to pursue and solve the world's great challenges.

The Center for Infrastructure Engineering Studies

The Center for Infrastructure Engineering Studies (CIES) is an interdisciplinary research center that provides leadership in research and education aimed at solving the problems affecting the nation's aging infrastructure.