Advancing Pavement Evaluation:
From 2D to 3D GPR and Continuous Friction Measurement

Seth Louviere, P.E.
Advanced Pavement Mgmt. Engineer

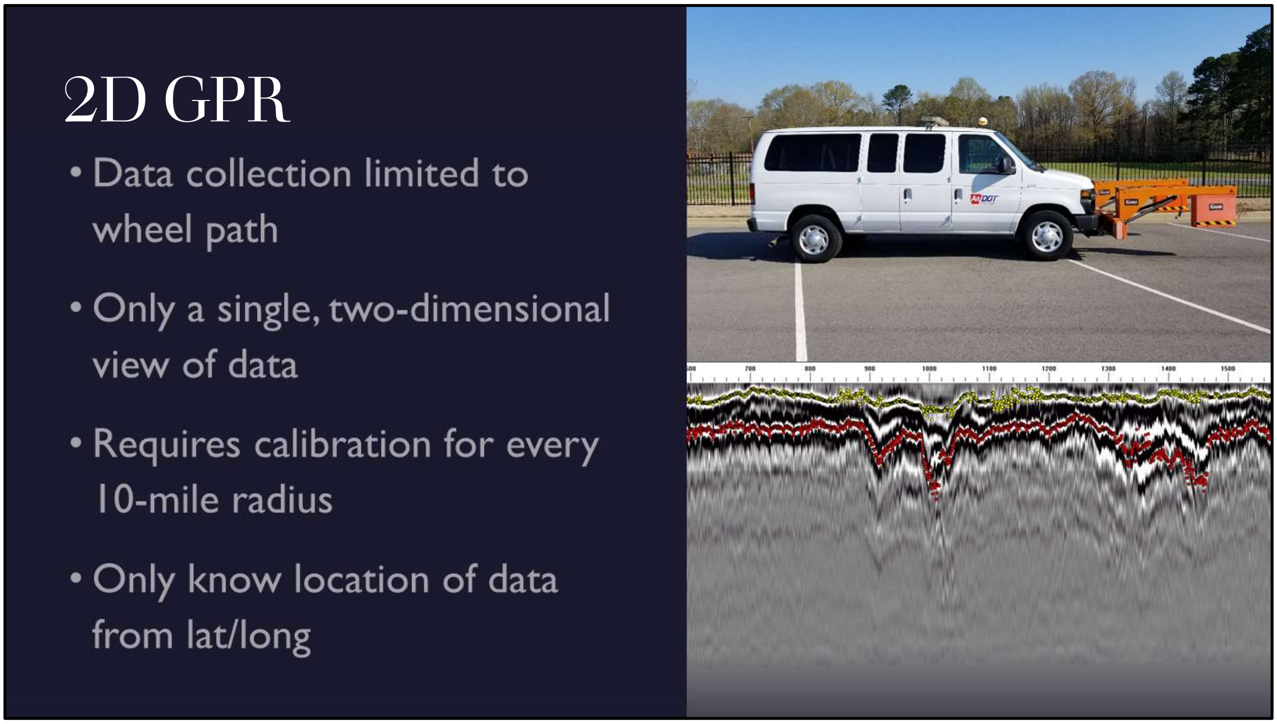
ArDOT Arkansas Department of Transportation

Welcome everyone. My name is Seth Louviere. I am an advanced pavement management engineer in ARDOT's Maintenance Division, and today I'll be sharing how ArDOT is advancing its pavement evaluation capabilities by transitioning from 2D to 3D GPR and exploring continuous friction measurement technologies.

What is GPR?

- Ground-Penetrating Radar (non-destructive, traffic speeds)
- Shoot EMPs into the ground
- Radar comes back to antenna very quickly (ns)
- Speed of returning pulses translates into depth/size/type of material
- Use this data to create imagery & find layer thicknesses

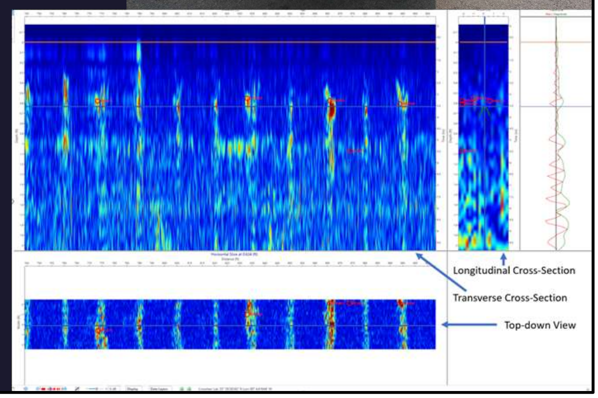
GPR stands for ground-penetrating radar. This is a non-destructive method for sub-surface investigations that can be performed at traffic speeds. The way it works is the antenna shoots an EMP into the ground (click for animation). That radar then dissipates as it travels further into the ground and reflects off the different materials underneath the pavement surface. When it reflects, the radar comes back up to the antenna (click for animation). This entire process takes only nanoseconds, which is how we can collect GPR data at traffic speeds. The speed at which the EMPs return to the antenna can tell us more about the depth, size, and type of materials underneath the pavement surface. This data is then used to create sub-surface imagery and find layer thicknesses. We then use this layer thickness data along with the deflection data from the FWD and traffic information to conduct our structural analyses.



Our traditional 2D GPR system has served us well but has its limitations—narrow coverage of only the wheel path, only a single 2D view of the data, frequent calibration stops every 10-20 miles, and, when looking at the data itself, the only way you can find the location is through lat/long. As you can imagine, this is not very conducive for a statewide, network-level data collection plan. Not to mention, that van you see there in that top picture is very old and makes for a terrible drive!

3D GPR

- 6.2’ of coverage width
- Three different viewpoints of sub-surface imagery
- No calibration required
- Location can easily be seen from map view (and lat/long)



With our new 3D GPR system, we can collect a much broader width of data, up to 6.2 feet. We can look at the sub-surface imagery from three different angles: the traditional transverse cross-section as before, the longitudinal cross-section (this would be like looking into a slice of the road in the direction of traffic), and the top-down view (like having a birds-eye view with x-ray vision). One of the best parts that our field crew really likes is that there is no need to calibrate the antenna at all with this new equipment. Also, in addition to the lat/long, you can easily tell where the data is located using the map view, or “overview”, as it is called in the software.

And this is just a screenshot of what the previously mentioned map view, or "overview", looks like. You can zoom in and out and move the map around. You can even change the map filter to be satellite imagery if you want. As you can see, this new 3D GPR system offers richer data and supports more thorough analyses.

Software & Usability

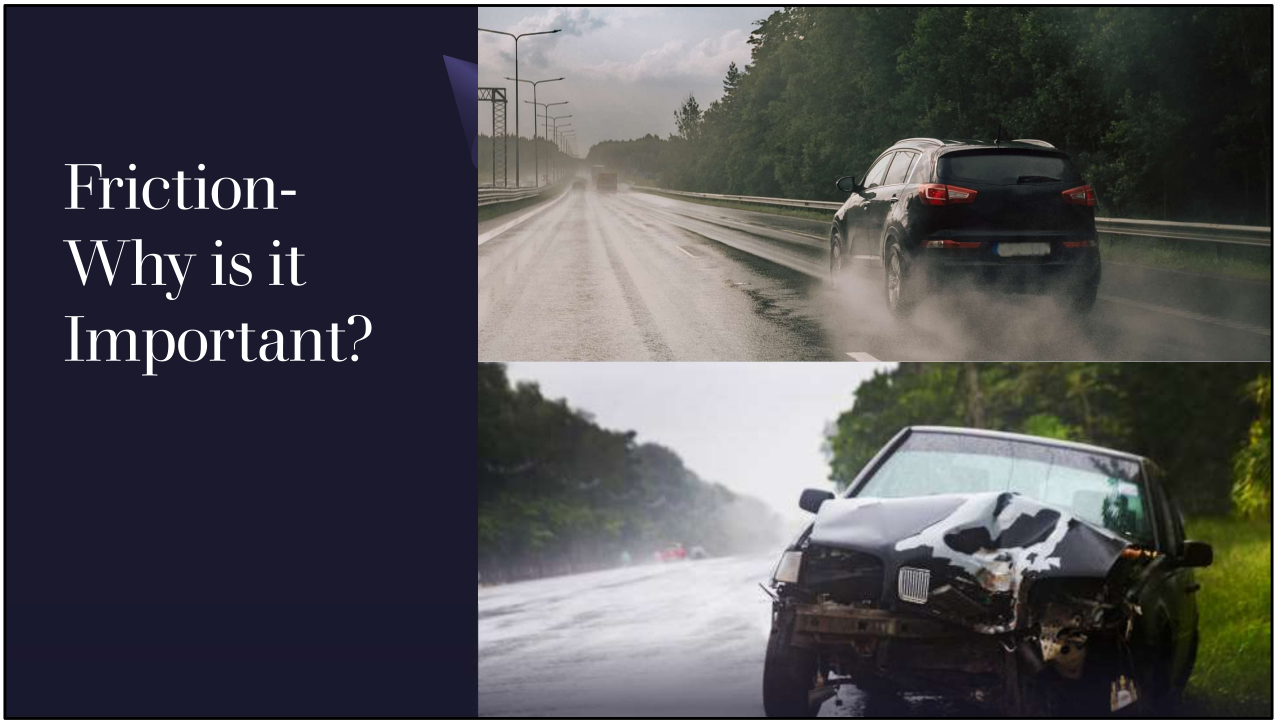
- Radan (2D Software): Geophysics background preferred, less-detailed analysis
- Examiner (3D Software): Intuitive interface, aerial & multi-angle views
- With Examiner, data can be shared via “Explore” viewer mode (no license required)
- “It’s so easy, an engineer can use it!” – Mert Su

As far as software goes, a geophysics background is preferred for Radan, which is the software used to analyze the 2D GPR data. Well, we don’t have anyone with a geophysics background in our office, so it ends up being somewhat of a less-detailed analysis with Radan. However, Examiner, the 3D GPR software, has a much more intuitive interface, multiple angles to view the data, and makes it so much easier to conduct a more comprehensive analysis. It even has a free “Explore” viewer mode so that we can share the data with others that don’t have an Examiner license! And I had to include this quote. So, several years ago, when we were still using the 2D GPR with Radan, we had a geophysicist in our office who did all the GPR analyses. Well, when we started looking into this 3D GPR technology (click for animation), this is what he had to say about Examiner. So, just a little something that speaks to the ease of use.

GPR Recap

	2D GPR	3D GPR
Coverage	Wheel Path	6.2 feet
Viewpoints	One	Three
Calibration Required?	Yes	No
Location	Lat/Long Only	Aerial Map View + Lat/Long

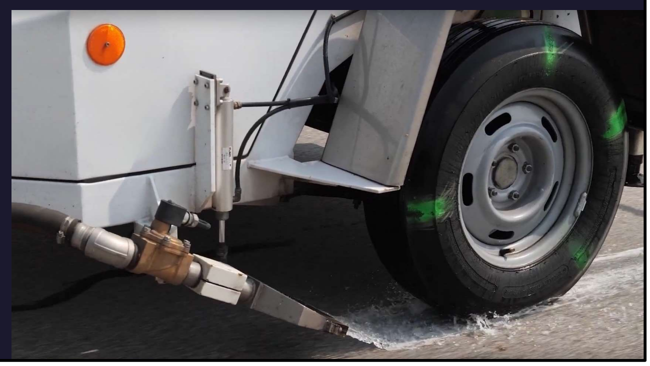
So, to recap, the 3D GPR gives us much more pavement coverage, more viewpoints to look at the data, there's absolutely no calibration required while we're out collecting with the 3D equipment, and the Examiner 3D software gives lat/long and an ariel map view for location. Needless to say, the 3D system makes our data collection and analyses much, much easier and more thorough.



So now we're going to switch gears and talk about friction. I know, the GPR stuff seems way cooler, but friction is important too! It's what keeps our cars like this (point to top picture) instead of ending up like this (point to bottom picture) when we're driving, and not just in wet weather either. Friction is that force that gives your tires grip on the road so that you don't go sliding like you're on glass.

Friction Testing – Traditional Method

- Dynatest Locked-Wheel Friction Tester
- Point data every 0.5 miles
- Limited speed range for testing (38 – 42 mph)
- No ROW imagery
- Very limited Interstate testing

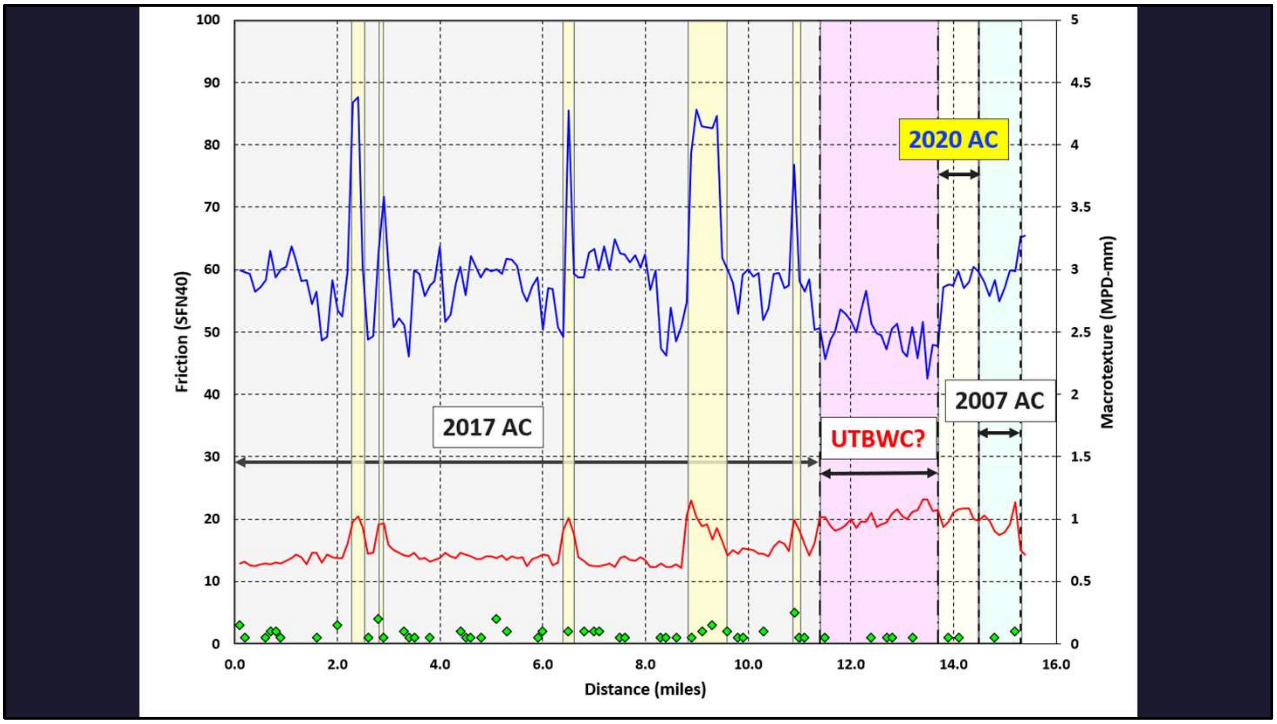


So how do we measure the friction on the road surface? Well, the traditional method that most DOT's use, including ARDOT, is the Dynatest locked-wheel friction tester, pictured here. As that trailer is being pulled along the highway, one (or both) of the wheels on the trailer locks up (you can choose which wheel you want to test with). When that happens, a stream of water is squirted from a jet in front of the wheel. This simulates a vehicle slamming on its brakes in wet weather conditions. From there, the sensors on the trailer measure the forces involved in this procedure, and a skid number is calculated ranging anywhere between 0-100. 0 is the worst-case scenario, and 100 is the best case. From there, we can figure out what surface treatment, if any, is needed to bring the right amount of friction back to the road surface. We usually collect statewide, network-level friction data at half-mile intervals. If we get a specific request for a road from one of the Districts or Traffic Safety, we'll test at a shorter, more appropriate interval. But I'm sure you can see how there is a lot that we're potentially missing in between those half-mile intervals. The tests must be conducted while traveling between 38 and 42 mph for the data to be valid. There is no video collected while these tests are being conducted. So, if there is a two-mile segment within a twenty-mile section of highway that is showing significantly lower skid numbers than the rest of the section, we can't be 100% sure what's causing that without going out and driving it ourselves. Also, due to the lower speed requirement for these tests, we only collect Interstate friction data when we receive specific requests to do so. And even then, we need traffic control and blue lights to comply with safety guidelines. So, you can see that there are several limitations to this method of friction testing.

Continuous Friction Measurement Vehicle (AKA: The SCRIM)

- Continuous data collection
- Speed range: 15 – 53 mph
- Forward-facing ROW imagery

However, ARDOT is currently a part of the research pooled fund study TPF-5(345/463): Pavement Surface Properties, Managing Pavement Properties for Improved Safety. As a member of this study, the Virginia Tech Transportation Institute, or VTTI, comes down to Arkansas every so often with their continuous friction measurement vehicle that's known as the Sideway-force Coefficient Routine Investigation Machine. That's a mouthful! We're just going to call it what they call it, the SCRIM. So, the sideway-force coefficient part comes from the fact that the wheel you see in the picture there is at a sideways angle of 20 degrees. This wheel tests similarly to the Dynatest model with the jet of water, except that it is measuring continuously instead of a fixed interval. This means no gaps in friction data coverage. It can also operate at a more varied range of speeds (anywhere between 15 and 53 mph), making it safer for both interstates and slower-speed roadways. The other great advantage that it has over the Dynatest model is that it has a forward-facing camera which allows you to see the surface condition at the time of testing. This allows for more informative decision-making when interpreting the friction data.



Now, I wanted to show yall just how useful this data can be. This data was collected in 2021 with the SCRIM. We looked up the job history for this route, and we were able to see some correlations between the job history and the friction numbers. We knew that this route had received some High Friction Surface Treatment several years before that. That's exactly why we told VTTI to come skid this route. And you see those spikes in the numbers? Look where that first big spike is around mile 2.2. Well guess what? (Next slide)

That's exactly where the first HFST job started! And we were able to easily see that, and many of the other "spike" locations, thanks to the video imagery that was recorded while this data was collected. Another thing to think about – we may have missed that HFST spot entirely if we were testing every half-mile. So, this is some really useful stuff.

Friction Testing Recap

	Dynatest	SCRIM
Coverage	Point	Continuous
Speed	38 – 42 mph	15 – 53 mph
Video	No	Yes

So, to recap, the SCRIM gives us continuous data coverage, a broader range of speeds to operate with, and ROW imagery. All of these factors make the SCRIM a much safer, more efficient, and more precise tool to measure friction along our road network.

So, in closing, we've got some exciting new technologies that we're working with in our pavement management section. I'm glad that we've gotten a chance to show them off to you today, and our hope is that these new advances in our pavement evaluation will help us in making more effective decisions to enhance Arkansas' road network for everyone! Thank you.