RED HILL VALLEY PARKWAY INQUIRY

TRANSCRIPT OF PROCEEDINGS
HEARD BEFORE THE HONOURABLE HERMAN J. WILTON SIEGEL
held via Arbitration Place Virtual
on Tuesday, April 26, 2022 at 9:30 a.m.

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Arbitration Place Virtual

--- Upon resuming on Tuesday, April 26, 2022
at 9:30 a.m.

GERARDO FLINTSCH; A WITNESS HEREIN

EXAMINATION BY MR. LEWIS:

Q. Good morning, Commissioner, Counsel. The first witness of the public inquiry is Dr. Gerardo Flintsch who is with us this morning, and Registrar, if we could call up Dr. Flintsch's CV, which is EXP73.

Good morning, Dr. Flintsch.

A. Good morning.

Q. And Dr. Flintsch, you have a 70-page CV, so needless to say we're not going to be covering all of it, just a few bits and pieces. Call up image 3, please. This is your CV?

A. Yes, correct.

Q. And just to start with your education, the second heading there on image 3, you've got a series of degrees in civil engineering from -- the first two in Uruguay and then in the US, culminating with your PhD in civil engineering from Arizona State University in 1996; is that correct?

A. Correct.
Q. And you are a chaired professor at the Via Department of Civil and Environmental Engineering at Virginia Tech?
A. Correct.
Q. And it's the Dan Pletta professor, that's just the name of the chair?
A. Correct.
Q. And how long have you been at Virginia Tech for?
A. Since 1997. Almost 25 years.
Q. And you are also the director of the Center for Sustainable and Resilient Infrastructure, otherwise known as VTTI. Could you briefly just describe what that organization is.
A. Sure. Our centre is a group of researchers that work on -- well, that I direct, that work on issues related with infrastructure engineering, and pavement engineering in particular. We are a collaboration between the Department of Civil and Environmental Engineering and the Virginia Tech Transportation Institute.

Q. And under areas of interest, at the top, you set out five principal matters. Where does friction science and measurement and friction management come in?

A. Yeah, is what we call vehicle road interaction.

Q. Vehicle road interaction?

A. Correct. That's where the vehicle contact the road through the tires, and friction is a very important part of that interaction.

Q. As well, pavement engineering and asset management --

A. Yeah.

Q. -- as well?

A. Correct, those are two areas where we -- of course with pavement engineering we try to design pavement to provide good friction throughout the life, and then within the asset management we would try to make sure that we maintain that friction over the lifecycle of the pavement.

Q. And transportation safety as well?

A. Correct. Yes. In that

area we kind of link the values, characteristics of the road with crashes and impact to come up with countermeasures that allow us to reduce crashes and then make the road safer, or even if we have crashes, to reduce severity of those crashes.

Q. And under "Teaching" if we could pull up images 4 and 5. Thank you. Just while the second one is coming up, at the bottom of image 4 under "Teaching" and at the top of image 5 there's eight courses. I understand you teach these courses -- from time to time, if not necessarily every single year?

A. Correct. The pavement design, I teach it almost every year. The others, depending on the scale, roughly every other year. It's flexible.

Q. I understand a number of them do deal with pavement friction issues like infrastructure, condition assessment and bridge and pavement management systems. Are those -- including friction within your teaching ambit?

A. Correct. This is part of the functional evaluation of the road. We do friction and dry quality assisted (ph), the key parameters we have it written on a regular basis for new pavements but also for exceeding pavement (indiscernible) throughout the lifecycle. We cover that in the classes.

Q. And then I see under number 7 is asphalt technology, and 3 is pavement design. Again, within that are they teaching about various types of pavements and mixed designs?

A. Correct, the asphalt technology focus on the design and all type of asphalt mixes, and then including the traditional mixes, Superpave mixes, (indiscernible), performa and porous mixes, et cetera. And then as part of the pavement design of course we would cover the basics for what type of results we expect from those mix designs and demonstrate friction and macrotexture, among other properties.

Q. On image 4 above "Teaching" there is "Awards and Recognition," of which there are a number of them. But the first one, you were appointed chair of the PIARC committee, assessment management of the World Road Association. What is that?

A. Yeah, the World Road

Association is an international organization, non-profit organization, that bring together road association from all over the world, including here in the US the national committee is AASHTO, American Association of State Highway and Transportation Officials. That is association of all the state departments of transportations. And I represent AASHTO in this committee that deals with practice of asset management worldwide.

Q. That's the PR committee?

A. Exactly.

Q. And then the third one is the H.W. Kummer lecture award, and is that one related to the vehicle pavement interaction as well?

A. Yes.

Q. ASTM committee?

A. Yes. This is award that is given by the ASTM E17 that deals with the pavement interaction and then covers all the standards related with the friction and macrotexture, as well as other pavement evaluation, pavement management and IDS. And I was -- it's an award and also kind of a keynote presentation at the annual meeting of the group.

Q. If we go to image 6 please, call up image 6. Now, there is many, many peaks of funded external research projects which I'm not going to go through, but let me highlight just a couple of them.

Do I understand correctly that the funded external research projects, these are projects in which you are or have been involved, often involving research and testing of various sorts. Is that a fair summary?

A. Correct. Yes, this is from some basic research, but mostly applied research related with the five areas we were discussing there.

Q. In the third column it says "PI." I understand that means principal investigator?

A. Yes, that would be the leader of the research group, and most of them I lead them. Not all of them. Some of them collaborate with other people.

Q. So, for example, the first one -- I'm going to go through any more than that. There's a large number of the ones that relate to tire road friction, pavement friction,

friction management, continuous friction pavement friction management.

But just the first one there, for example, is one that's ongoing, district level pavement friction level program implementation for the Virginia Department of Transportation which you're the principal investigator on. And then the co-principal investigator is De Leon, who is someone you collaborate with frequently I understand.

A. Yes, he is a former PhD student at Virginia Tech, is the leader of that program within our centre.

Q. And then call up image 13. This is the beginning of a long list of papers and refereed journals, and without going -- one can word search for friction, but again there's quite a number of them within the journal section that pertain to friction, friction management, related topics; is that correct?

A. Correct. And friction measurement and relationship between crashes and friction too.

Q. For example, at image 13, same page at number 9 there's a review -- the second one from the bottom, "Review on Machine Learning Techniques For Developing Pavement Performance Prediction Models," that's a recent paper, correct?

A. Correct. Rita Justo-Silva, she is a student University of Coimbra, Portugal, but I co-advising her. It's international co-advising.

MR. LEWIS: And Commissioner, there's a large number of these. I don't propose to take Dr. Flintsch through them but I just highlight the first one for reference.

I would ask to make Dr. Flintsch's CV an exhibit which I believe would be Exhibit 12.

EXHIBIT NO. 12: Dr. Gerardo Flintsch's curriculum vitae

MR. LEWIS: Registrar, thank you.

BY MR. LEWIS:

Q. Now, if we could call up Dr. Flintsch's report, which is EXP189. This is a report titled "Primer on Friction, Friction Management, and Stone Matrix Asphalt Mixes," dated April 2022, 40 pages long prepared for this inquiry. Just to confirm this is your report, Dr. Flintsch?

A. Correct.

Q. And are there any changes or corrections you need to make to your report at this time?

A. Not at this time.

MR. LEWIS: And just generally in terms of organization of your report and more or less how I would like to go through it today, Commissioner, is more or less in order not covering every last word of course.

Part 1 is an introduction to pavement friction dealing with the definition and the science behind friction and friction measurement, and then the components and devices involved in measuring friction and interconversion of friction measurements between different testing methods, broadly speaking.

The second part is pavement friction management which there's a number of areas to look at, including friction investigatory and intervention levels in a number of jurisdictions and as well friction remediation methods.

The third part is on stone matrix asphalt or stone mastic asphalt. And we will take it more or less in order. Also a slide deck. Actually if we can make this report an exhibit, 13.

THE REGISTRAR: Noted, Counsel. Thank you.

EXHIBIT NO. 13: Report titled "Primer on Friction, Friction Management and Stone Matrix Asphalt".

MR. LEWIS: Slide deck as well, which I don't think has a document ID yet, I think it's Gerardo Flintsch slide show. If we could pull that by the side of the report.

Registrar, is there an issue with the slide show?

THE REGISTRAR: Sorry, counsel. One second. I just have to re-start the OnCue.

BY MR. LEWIS:

Q. While he's doing that, Dr. Flintsch, there's a slide deck which we're trying to pull up which I understand you may refer to from time to time during your evidence, and I understand you prepared it as a demonstrative aid to complement your presentation today, correct?

A. Correct, most of the slide are just reproduction of the figures within the report, but there's a few that expand a little bit.

MR. LEWIS: And I believe that's a 16-page document, although substantively I think the slides are on 13 or 14 of those slide pages.

If we can make that an exhibit as well. Number 14.

THE REGISTRAR: Noted, Counsel.

MR. LEWIS: Thank you.

EXHIBIT NO. 14: Gerardo Flintsch's slide show.

MR. LEWIS: And then in your report, Dr. Flintsch, we go to image 4 there's a list of acronyms that you've set out, and there are a lot of acronyms in pavement technology, as I've learned. And there's one page of selected ones, and I just want to look at a few of them before we dive in.

First one you've already

mentioned is AASHTO, the American Association of State Highway and Transportation Officials. And I think you've already described it. It forms a lot of committees and it sets standards and guidelines of various sorts; is that correct?

A. Correct. It's similar to the Transportation Association of Canada.

Q. And ASTM, ASTM International, formerly the American Society For Testing and Materials, what's that?

A. That's a non-profit again that deals with all type of testing and procedures related with all type of materials and processes and so on from highway materials to medical devices and things like that. But it originally was a US-based association but through partnership with international standardization groups they become ASTM International just a few years ago, maybe more than a decade or so.

Q. And then there's a number of acronyms that pertain to certain numbers that are friction measurement numbers, and I'll start with the BPN, B as in Bob, which is -- that's the British pendulum number?

A. That's correct. And when

we refer to numbering in the friction world we are referring to the coefficient of friction that is a physical property we can measure --

Q. If we could wait for that for a second because we will dive into that. If we could just talk about the acronyms here because we're going to see them throughout.

A. It's just coefficient friction times a hundred, that's what we call the number.

Q. For the British pendulum number?

A. Yes, the same for all type of devices, like friction number or the skid number, those are the coefficient of friction times a hundred.

Q. So the grip number that's GN, and then there's SFN which is the sideways force number?

A. Hm-hmm.

Q. And the SN which is the skid number, measured with a locked wheel tester. And these are I think you said all different ways of expressing the friction value taken from the coefficient of friction taken by different measuring devices; is that correct?

A. Correct.

Q. And without presaging it too much, the same number affixed to one of those acronyms doesn't necessarily mean the same level of friction; is that correct?

A. That is correct.

Q. Call up image 5, please, of Dr. Flintsch's report.

Now, before getting into the science of pavement friction could we just look at the first sentence of your report at the top of the page under "Introduction to Pavement Friction." And referring to the frictional properties of pavement play a significant role in road safety as the friction between tire and pavement is a critical factor in reducing potential crashes.

Why do we care about friction? Why does it matter?

A. Well, friction is very important because, as I mentioned earlier, the area of contact between the vehicle and the pavement is the area where the tire touches the pavement. So there's a relationship between the friction that can be developed in that interface between the pavement and the tire given by the friction and the potential for a crash.

Crashes are seldom caused by friction, although in a few exceptions there are, but most crashes happens because of a combination of factors such as distractions and maybe excessive speed, lack of reaction, et cetera, but if you had good friction between the tire and the pavement you may be able to even reduce the severity or avoid the crash altogether because you will be able to develop enough forces to either slow down or handle the vehicle properly.

Q. So typically pavement friction can be a contributing factor but it isn't typically the only factor?

A. Correct.

Q. And conversely, if pavement friction is adequate or even excellent does that mean collisions won't occur?

A. No, no. Because there's always other factors that happen. Again, if you fall asleep in the car there's no friction that will help you.

Q. Fair enough. Then is

there any reason to measure pavement friction other than ultimately in relation to road safety?

A. Not really. We do use again friction and macrotexture as we see, what we call frictional properties of the pavement, as an indication of pavement safety. That's why we measure friction.

Q. So looking at the whole page again, Registrar, please. So in section 1.1 you set out the definition of pavement friction. If you could explain that a little bit for us.

A. Yes. Pavement friction is the force that -- the way that the force that resists the relative motion between the vehicle and the pavement surface. That's the definition of AASHTO. And in short, what it is is a force that is developed as the tire start to either slow down or transverse a curve, it's the forces that develop at the interface, and those forces divided by the vertical force is what we call a pavement friction. And -- and if we can go to the second -- the first slide in the presentation it kind of illustrates that.

Q. Registrar, slide 2, please.

A. If we look at it --

Q. Go ahead.

A. The tire pavement interface is with --

Q. Sorry, Dr. Flintsch, there was a glitch there so I wonder if you could start again from the moment that you started speaking about this slide.

A. Sure. When -- as I mentioned before, when we were driving the vehicle and we try to brake or try to maneuver a curve or swerve to change lanes or something like that, then that is the force that is developed at the interface between the tire and the pavement. If you divide that force by vertical force that is applied on that tire and you add it for all the tires that's the coefficient of friction.

Q. The coefficient of friction?

A. Yes.

Q. The -- and then on your slide there and as well in your report images -- starts at page 5 and moves onto 6, you explain the concepts in relation to the coefficient of friction of adhesion and hysteresis. Could you perhaps describe those for us.

A. Sure. As Andrea was saying, there is two components of friction that provide that force that develop between the tire and the pavement. The first one is adhesion component, and that comes from the --

Q. The adhesion component?

A. Correct.

Q. Thank you.

A. That comes from the contact between the tire and the pavement and mostly the coarse aggregate that protrude from the pavement and is in contact with the rubber. There is some physical forces that develop there that of course produce some wear out of the tire but also provide the force that allowed the vehicle to slow down or to control on the -- keep control to curves, et cetera. And that forces work with the pavement is wet or dry. Of course we'll discuss that later.

But the other component is the hysteresis part that deals more with the deformation of the rubber to adjust to the macrotexture of the road, the irregularities of the road. The rubber will deform and recover, and there's losses of energy with that deformation and that also contributes to braking to provide more friction.

So the sum of that forces that came from the dose of energy at the tire and the adhesion between the tire and the aggregate is what that -- that to become the friction that is available for the vehicle to brake or maneuver.

Q. And then you've related in between figure 1 and 2 on your slide show to the concepts of pavement texture, microtexture and macrotexture, if you could explain for us.

A. Sure. In highway engineering we have define a whole spectrum of textures on the irregularities in the surface of the pavement with respect to a completely flat area.

So if you look at the other one, two of those actual wavelengths or, sorry, ranges, correspond to the two main pavement surface properties that contribute to friction. They -- on the final side on the various small irregularities in the actual stone itself in the aggregate that show up on the surface of the pavement, that you see there are small irregularities, small bumps in the order of half a millimetre, very, very small, this is what we call microtexture. And again that microtexture is what provide adhesion between the aggregate and the rubber of the tire.

And then on the other side you have the macrotexture. One is the bigger wavelength and amplitudes and that has mostly to do with how much the aggregate sticks out of the surface of the pavement, of the asphalt that glues all the aggregate together. And this is talking about from about .1 millimetre to 20 millimetres in amplitude, and also -- so in this case that particular property relates with the hysteresis part that we mention before. So most microtexture and macrotexture contribute to friction and we need to make sure that both are adequate to provide good friction.

Q. So then colloquially we could say that macrotexture is the entire portion of the aggregate that pokes out of the asphalt surface, whereas microtexture involves the little bumps on the surface of those same large aggregates. Is that --

A. That is correct.

Macrotexture is something you can see when you look at the pavement. The microtexture is mostly you have to feel -- you have to touch it to be able to feel it....

Q. And call up image 6 in the report please, Registrar. While he's doing that can you comment on the general effect that microtexture and macrotexture have on frictional properties, so they both have an effect. If you could speak to that.

Sorry, image 7 actually, Registrar. I apologize for that.

A. Okay. Yes, the microtexture, as I said before, it is the adhesion component that provide adhesion component of the friction. So in that case it's important that all the speeds -- excuse me -- is important at all the speeds when the vehicle is driving on the road because again provide -- it comes from the contact between the tire and the aggregate itself.

On the other hand, the macrotexture, it depends a lot on the speed of the vehicle. So the higher the speed the more important the macrotexture becomes. Again there is less time for the tire to deform and there's more energy dissipated in terms of hysteresis.

So when you go to higher speeds microtexture kind of becomes a little bit more important; at a lower speed macrotexture is more important.

Q. And then the next section is "Friction During Braking." So we move on from the components of friction to the operations where it's important for us.

So the first thing in your report in section 1.1.3 at the bottom of image 7 is friction during braking. And I understand there's also friction during cornering is the other factor. So can you start with friction braking on a straight section of road, which is the section that has been called up. Can you explain how that works.

A. Sure.

Q. Is there slide 3 perhaps is --

A. Yeah. If we could go there that would be useful.

Q. If you could drop that expansion and call it -- yeah, thank you. Slide 3.

A. Okay. So what happen is when the vehicle is circulating, and normally on road there's almost a static contact between the tire and the pavement as the tires rotated and that pushes the vehicle before. So there's very little friction developed there. Of course there is some (indiscernible) resistance that relate with gas consumption and energy consumed to move the vehicle forward, but again there is very little slip between the tire and the pavement so the contact pushes the vehicle forward.

Q. Dr. Flintsch, is that very little slip?

A. Yes.

Q. Thank you.

A. So when they start to brake then the tires start to rotate a little bit slower than they would rotate normally and then the rubber start to slip with respect to the pavement. And so if you see the red curve in there, in the figure on the right you see there the beginning where the friction start to increase because the slip start to increase all the way until you reach a peak --

Q. Call it peak friction?

A. Yes. And you have a peak friction that correspond with what we call critical slip. The percentage of the slip between the rubber and the pavement, and then after that it continued to do more all the way until the tires complete -- the tire goes slower, slower, slower with respect to the free-rolling speed until it's completely locked and you have full sliding of the pavement -- of the tire with respect to the pavement of the right of the curve. And that happens when the tire is completely locked and that's what they call a hundred percent slip.

And then on the other side you have free running would be a zero percent slip as I mentioned before, so --

Q. So the tire influence area on the left is where the tire is slowing down during braking until it reaches the peak friction at which point the tire starts to slip or slide across the pavement surface while it's still rotating; is that right?

A. Yes, actually the tire is always slipping, but it gets slipping more and more as you move from the left to the right. Of course when -- before you start braking there's almost no slipping, but then it starts to slip, it reach a peak, and the right -- the left side of the curve is more influence by the type of tire and the condition of your tire, and then on the right part that's more influenced by the pavement surface properties, mostly micro and macrotexture as we mentioned before.

Q. And then figure 4 is also -- if we go to slide 4 -- this is figure 4 from your report. Could you describe what we're looking at here.

A. Sure. This is similar to the figure before. On the vertical axis you have the coefficient of friction in the instance within the braking maneuver, and on the horizontal axis you have the slip from zero to a completely locked wheel.

So the right curve there, which is what we will call a typical wet friction curve for the pavement with good micro and macrotexture, meaning when I said, wet friction, that's typically what we measure in highway engineering is we spread water before we slide the rubber with respect to the pavement.

If you do the testing without spreading the water before then you will have -- and this is just not to scale but just to illustrate the trend -- you have a dotted blue line on the top where you have higher friction and less effect of the friction with respect to the slipperiness between the payment and -- or the slipping percentage between the pavement and the tire.

So when you have dry pavement typical friction is high throughout the whole braking period, but when you have a wet pavement then the macrotexture becomes an important factor because it provides the slope or how fast the friction decreases with increasing the slip or increasing the speed of the vehicle too.

So there you have the green line shows what will happen if you have a pavement that has good friction but it has low microtexture. So the small little asperities, and depend on the aggregate what will happen is you will lose your friction faster as you increase the slip or your speed of your vehicle in a way.

Q. Sorry, that's the second line from the bottom, the second lower line, the green dotted line is where there is low macrotexture?

A. Yes, correct.

Q. Thank you.

A. And then if you have bad macrotexture you will have lower frictions throughout. The idea here is that when the pavement is wet macrotexture becomes quite important too, and also it become relevant when we try to interconvert between different skid measurement devices.

Q. And just this particular figure 4 is -- again it's directional, it's not to scale or anything; this is a demonstrative aid; is that correct?

A. Correct. And again how high and how steep the lines are will depend on the actual values you will have in the pavement based on your mix design and construction.

Q. And then image -- the next page, image 8 on the report. The same thing. So if we go to image 9. Those are the ones we just looked at. Thank you.

The next section in the middle of the page is "Friction While Cornering" which is a somewhat different concept, if you could describe that, please.

A. Sure. When you need to transverse a curve you also need some forces that allow the vehicle in this case to avoid getting off the road and sliding transversely.

Q. Sliding transversely?

A. Correct. So the idea is that the geometric design kind of the road generally accounts for a little bit of that, but depending on your curvature and your superelevation transversal profile, then you still need some forces that allow the vehicle to move along the curve without -- because there is centrifugal force will try to push the vehicle outside the curve, especially if you are going a high speed, so you need that force provided by friction to keep the vehicle in the right trajectory along the road.

So that's another --

Q. Superelevation, that's a banked curve?

A. Yes.

Q. Sorry, I cut you off.

A. That's fine. The idea is

that friction avoid the vehicle to slip sideways and then you are able to transition your curve properly if you have good friction.

Q. And then -- sorry, go ahead.

A. No, sorry.

Q. Then there's the issue of simultaneous cornering and braking --

A. Yes.

Q. Further down -- if you could call that out.

A. And maybe go to the next figure in the presentation too.

Q. Don't expand that. Go to the next slide 5.

A. If you see here we have two components of friction that is needed again to maneuver safely a vehicle, and for any vehicle with safety type of tires and condition of those tires and condition of the pavement they will be like an envelope that provide how well that vehicle can do, the maximum performance in a way without losing control.

So you see there you have like a red arrow for braking. That's the maximum braking that you can have, and then green you have in the other direction, in the corner direction the maximum cornering that can be provided. And there you see when you try to maneuver a curve and maybe you had to break because something happened that curve, that's a vehicle in front of you slow down or there's a pothole or any type of reason that you may have to try to brake, then what will happen is you will need to use the friction that is provided between the tire and the pavement, and divide some friction for cornering and some friction for braking.

So really you will have less friction that you normally have for braking and you have less friction that you normally have for cornering. So the whole friction that you need is the -- results from these two components in a way.

Q. So there's only so much available friction and it has onto be divided -- has to be split between these two components.

A. Exactly.

Q. Okay.

A. And again, if you look at the last part in that section, that when the vehicles use antilock brakes today what they are trying to do is try to keep the sliding in that area where you have the highest friction close to that big friction that we talk about before. So it's important in both cases because it allow us to develop more forces that help you keep control of your vehicle.

Q. So with antilock brakes it never gets to the locked -- the hundred percent locked portion of the low end on the right side of the friction curve that you described?

A. Yes. The brake continues to apply force on the tires to slow you down but trying to get the slip -- the optimum slip in a way.

JUSTICE WILTON-SIEGEL: So if I could ask Dr. Flintsch, going back to the previous comment. For any given surface, depending upon how much cornering is involved, the same friction level can be more critical if there's more cornering involved than if it's flat.

THE WITNESS: Exactly, because you still have to provide a little bit of friction to brake because you never know when you have to brake. So yes, that's correct. The demand for friction is higher on curves, and the sharper the curve, the lower the radial curvature, the more friction you will need in that curve.

BY MR. LEWIS:

Q. Am I correct that this superelevation also affects that, that you were speaking of? If you have a banked -- a superelevated curve that also assists in keeping the car on the road?

A. Exactly. Correct.

Q. If we could move on to measuring friction. It starts at the bottom of image 9 and goes on to the top of image 10. We're going to hear from you about a number of different types of friction measuring methods and devices, but if I understand your report correctly, and you already referred to this a few minutes ago, I mean, there's a few large and obvious commonalities and lot of differences with different devices.

The common feature that you referred to I think is that all the measuring methods for friction measurement -- not macrotexture but friction measurement -- all rely on the principle of sliding rubber over a wet road surface and measuring the friction forces; is that right?

A. That's correct.

Q. And then if we can go to image 10 which is the next page. I think that -- at the very top it talks about the measuring wet friction after spreading a small amount of water on the pavement. But then the different devices use different types of tires, different water film thicknesses. There are different operating principles, and the speed at which the testing device operates is often different, all of which affect the friction measurement output; is that right?

A. That is correct.

Q. And so even if you are -- this is a general proposition -- even if you are measuring the same stretch of pavement, different devices will typically return different friction measurement results?

A. Correct.

Q. Okay. And one of the variables that I mentioned there is testing speed, the speed at which the -- whatever testing device it is, at the speed at which it operates. And am I correct that the higher the testing speed in general the lower the coefficient of friction measured; is that right?

A. That is correct, yes.

Q. And then if we could take away that and go to the next slide, slide 6, which is three of the photos are the same as on image 10 of your report but you added the British pendulum test. And if we go to image 11 in the report. This is a description of different types of measuring equipment, and I wonder if we could go through those starting with the first one that you describe in your report on image 10 which is -- don't expand that please because he's also going to be looking at the images in the slide slow. Thank you.

So we can start with sliders, the British pendulum method.

A. Yes, correct. The British pendulum is a device that was developed originally in the United Kingdom by the Transport Research Laboratory. It used to be an official national laboratory but now it is a private company.

But the pendulum is a little rubber slider that is placed on a pendulum that is dropped, touches the pavement and then goes up, and then depending how much friction -- how much force the pavement applies on the slider depending on the friction would be how much energy is lost. So you can easily measure that on a scale that is provided in the left side of the apparatus there with -- and that's what it is, the British pendulum number, or BPN. It's just something you read and you know how much energy is lost. The higher the number, meaning the lower the pendulum go up after touching the pavement because there would be more energy lost from the friction contact between the slider and the pavement.

Q. Registrar, if you could expand the photo -- the upper right photo on the slide. I don't know how clear it will be when you expand it. Yes, that one.

That's the British pendulum?

A. Yes, exactly. And you see there if you start if there is no friction the pendulum will go all the way up on the right, and depending on how much energy you have different numbers there that you can -- on the circular scale on the left.

Q. Okay. On the circular --

the quarter circular version of it?

A. Yes.

Q. And sorry, you said water is also used as part of the British pendulum test?

A. What you do is you spread a little bit of water to -- and then you will do the -- first you make sure that when is vertical the pendulum touching the pavement, then you lift it, you broke it, you spread water and you let it go and then you measure the BPN.

Q. Okay. And if you could reduce that. Thank you.

JUSTICE WILTON-SIEGEL: Can I just ask, is there any recognized scale for the results, a scale that indicates what an acceptable pendulum number would be and one which would be unacceptable?

THE WITNESS: Yes and no. There is some values that are specified in some of the standards. For example, when you are looking about aggregate you will use the pendulum to test the properties after they have been polished, and we are going to get into these later on, but there you have -- some agencies have some numbers that they require after polishing for so many hours the aggregate should remain with these BPN, but it's not one standard number that you can say is applied to all type of roads.

Again, a key part of the physics of this is that this pendulum only measures the microtexture because the test is done at the very lowest speed of the sliding between the pavement and the rubber sliding and the device.

BY MR. LEWIS:

Q. Dr. Flintsch, the test you were talking about, was that the polished stone value test that you were referring to?

A. Correct.

Q. And we will come to that specifically.

And as well, Commissioner, I anticipate we'll be hearing evidence from Ministry of Transportation witnesses as to their approach to polished stone value and the pre-approval of aggregates.

There's an ASTM standard for the British pendulum test. Am I correct from your answer that within that standard there's no stipulated acceptable reading?

A. Correct, correct.

Q. The next type referred to are the longitudinal friction coefficient measurement equipment. And I would like to deal with -- there's two types that are listed, the grip tester and locked-wheel friction testers, and I wonder if we could talk about, in reverse order, the locked-wheel friction testers first.

A. Sure. The lock wheel test is call (indiscernible) device used in North America for many years, and what it is is a trailer that is pulled by a pickup truck that has a water tank in it. So the trailer has two wheels and it locks one of those wheels completely. So it goes through the cycles of starting to lock, and then when it lock completely it takes a measure for a period of time, typically about one second or so, and provide an average value for the force, and then that force is translated into a coefficient of friction and multiplied by a hundred to provide a friction number or a skid number.

And again this trailer has been used for many years and it has an ASTM standard is 274. And it's useful equipment, it provides a lot of information, but that only can measure on a sample of the pavement, and I'll come back in the next section of why that is important. But the idea is you completely lock the wheel, measure the average force over a period of time, that period of time can be changed, but it is specified in the ASTM 274. And then --

Q. What is specified, sorry? I didn't catch that.

A. The time where they use to average the wheel lock friction.

Q. Just in terms of the friction curve that we're talking about, as I understand it it's measuring at the right-hand side at the hundred percent locked wheel, the hundred percent slip; is that right?

A. Correct.

Q. And it produces a skid number or a friction number, SN or FN, right, which are the same thing?

A. Correct, yes. Just over the years most of the standards for ASTM and AASHTO are the same, but in some of them AASHTO has decided to just kind of change the terminology, and so in a way to become kind of looking at the property or trying to achieve with your pavement. So instead of using skid like they decided to use friction because you want to have good friction. Similar thing happened with the roughness and smoothness. They are both same properties but they are called different by ASTM and AASHTO.

Q. Okay. AASHTO uses FN, or friction number, and ASTM uses SN or skid number?

A. Yeah.

Q. Is that right?

A. But other than that the standards are almost identical.

Q. And again the standard doesn't set out a specified level of friction which is acceptable or sets out how to do the test and how to record the results?

A. Exactly. You could try to define values, but those are then more on the related crashes with friction than on the test itself.

Q. Then the grip tester is the next one, or fixed slip friction testers. Sorry, on the slide, the first thing, it's the bottom right on the slide there, that's the --

with the white truck and the trailer, that's the locked wheel ASTM tester; is that right?

A. Correct.

Q. And then the grip tester, which we're about to talk about, that's the one with the black truck with the little yellow trailer; is that right?

A. Yes, exactly, a white truck with a dark water tank on top.

Q. That's the big water tank in the back?

A. Yeah.

Q. So if you could tell us about the grip tester.

A. Sure. The grip tester also measures longitudinal friction, but what it does, it has a wheel that is forced to rotate slower than the pre-rotation. So it's always slipping with the pavement about 15 to 18 percent and it's through a chain. So it's physically retrained from rotating freely so it's always sliding. And this device is a little trailer. It's very light. And it's used a lot in airports to where they periodically monitor friction on the runways and for, of course, providing good friction for the airplanes when they trying to land.

You can -- but it's been used in the highways, and we even use it here in the US for a few (indiscernible), and we have a demonstration project for a while. Again, just plain water and then you measure the force, the vertical force and the resultant (ph) force, and then you calculate the coefficient of friction and then you multiply by a hundred and you report the grip number.

One advantage of this device with respect to the locked wheel is that you can -- since there is a smaller wheel you need less water because you had to cover a thinner area of the pavement, and again it's slipping -- it's working at the lowest slip and so you can continuously measure. If you try to lock the wheel completely you'll use your tire very, very quickly in this case. The tire can work for many, many miles so you can measure continuously on highways.

Q.   Because it's got continuous friction --

A.   Friction measurement.

Q. And so the wheel is always moving during the testing that is going on, unlike the locked wheel which, as you said, periodically locks in order to take the test results?

A. Correct.

Q. And then the grip number is the number that ultimately comes out?

A. Yes.

Q. Gets produced.

And then the next one is the sideway-force coefficient measurement equipment, most commonly used on being the SCRIM, the sideway-force coefficient routine investigation machine. And in your slide, that's the big orange truck there.

A. Yes.

Q. That's one type of that, but I gather the most common one that you indicate is used?

A. Yes, this is the most common one, although there are other manufacturers that produce devices that use a similar principle that's not called a SCRIM, but they basically use the same technology.

Again, in this case the technology was developed by TRL, the Transport Research Laboratory in the UK, and it's licenced to a company, WDM, that produce this system. And in this case what it is is a smaller wheel which looks like a motorcycle wheel with no tread, very, very -- bald in a way. And that wheel is placed at the little angle with respect to the direction of travel.

So when the wheel is -- and it has a vertical load of 200 pounds applied, and then when the vehicle is pushing forward the wheel try to become parallel to the direction of travel. So the higher the friction the more force that you will -- the wheel will make to become parallel, so you measure that sideway-force and divide it by the vertical force again to get the coefficient of friction and then get that sideway-force friction coefficient that you can convert into a sideway-force number that is just a hundred times the coefficient.

Q. So the wheel in this -- it is again a continuous friction measurement device that, like the grip tester, is continual throughout the testing area?

A. Hm-hmm. Correct.

Q. And then if I'm doing it correctly, instead of the wheel being angled in the direction that one is going, it's at a bit of an angle?

A. Correct.

Q. And then we'll get to a few more specifics about these devices but there's two other types that you mentioned, decelerometers and kinematics and sensors and -- are either of those used in the same way as the ASTM locked-wheel tester, the grip tester, or the SCRIM for --

A. Not yet. Decelerometers devices are -- they are used sometimes for winter maintenance to test on ice and snow-covered surfaces. And eventually they could be used, but they are mostly on the experimental research projects. And similarly with the vehicle dynamic, there is a lot of technologies that are being developed that are not used on a regular basis yet. I would say they are research basis still.

Q. Research basis?

A. Correct.

Q. If we go to image 12,

please.

This section, some of it you've covered already so I just want to hit on a few additional things. The ASTM standard for locked-wheel testers, as I understand it, stipulates how to report the speed of the testing and the type of the tire that's used; is that right?

A. That is correct.

Q. And the standard speed under the ASTM standard for locked-wheel tester is 40 miles per hour or 64 kilometres per hour, often rounded to 65, I gather?

A. Correct. In the -- if you report it in kilometres per hour you use brackets around it, and if it's in miles per hour you just specify the number. So you have a friction number FN40 and a 64 or 65 in brackets, is the same number.

And then the other thing you need to specify is the type of tire that you use for the test. Originally they tend to use a ribbed tire, means a tire with threads.

Q. A ribbed tire?

A. Correct.

Q. And. And that type of tire is very sensitive to microtexture, but since the water is allowed to flow in between the treads then it's not very sensitive to the macrotexture.

So few states in the US have adopted a bald tire or a smooth tire that doesn't have any tread. It kind of simulates the worst conditions when somebody is using tires that are past the legal limit and had no tread in them. And in those cases the values that are reported provide a lower value than what you will get with a ribbed tire, and in this case is more sensitive to both micro and macrotexture. And also to the condition of the testing too so...

Q. So even within the ASTM locked-wheel tester, depending on which type of wheel you use, whether it's ribbed or smooth, will affect the friction number or skid number that is produced. If you use a smooth tire it will typically produce a lower friction number?

A. That is correct.

Q. And then those are indicated in accordance with the ASTM standard by at -- there's an R is used at the end of the -- so if it's SN(65R), that means the test has been done at 65 kilometres an hour with a ribbed tire; is that right?

A. Correct, or an S if it's smooth tire.

Q. At the end of page 12, image 12 there, the last paragraph refers to it being a key limitation of locked-wheel testers is that they can only sample the pavement surface by repeatedly collecting data on short segments of road and do not effectively differentiate the changes in friction along the route corridor.

Is that just referring to what you said earlier about how it's periodic testing as opposed to the continuous friction measurement of the grip tester and the SCRIM?

A. That is correct. We always sample a smaller area and then -- and again a little bit that the operation you have the wheel to rotate three and then you lock it and you (indiscernible) then let it go, that is also the amount of water they use, just take how many tests you can do per mile.

Q. And you can't skid for several kilometres or miles because that would --

A. That will use your tire,

yes. The wear will be -- and then again you will leave skid marks eventually. So you only do sampling of the road. And again the other problem you could have with a locked wheel is since you are locking one of the wheels and if you have sharp curves you also may lose control of your vehicle because it may start to kind of swerve along the lane.

Q. So you're referring to on a steep curve you could lose control of the tester and essentially the tester itself skids out. Is that typically a problem when you're on a limited access highway with superelevated or banked curves?

A. Not really. If you have high radius curves and you had good superelevation you probably should be able to do this. That is also depending a lot on the skill of the operator too.

Q. And if we go to image 13, the next page, just at the top. I think you covered this, but the grip tester, as I understand it, has been used more -- in highways in the UK for many years; is that right?

A. That is correct. Similar

countries, UK, Chile, and even here in the US for some project we have used it.

Q. In terms of the US, I think you indicate that it's been used in the US since about 2008 below figure 6 there in the US, but more recently it's been the SCRIMs that have been used?

A. Yes. And there is two main reasons why we switch, and in this case is a project that our research group led, me in particular. We did several demonstration with a grip tester, but typically runways, they are very smooth and they don't have a lot of effect because they get very high maintenance.

When you get a long segment of roads the little trailer with the irregularities in the road kind of bumps a lot, so it cause a little bit of issues of repeatability of the measurements. Not a lot but it is a factor. If your smooth surface is high, it's not very smooth road then you could have some problem.

Q. Did you refer to the -- it can cause some problems with the repeatability of the results?

A. Correct.

Q. When the road is overly rough?

A. Yeah.

Q. Which is not typically what you get on airport runways which are shorter than roads and tend to be well maintained. Does that summarize correctly?

A. Correct. And the other limitation is that for production microlevel screening you also want to measure a lot of miles without meaning to refill the water. So that's why the SCRIM with a big truck and a big water tank is more efficient in terms of productivity.

Q. Right. It's a big device. I take it it's also probably a more expensive device; is that correct?

A. Yes, it is -- you're talking an order of magnitude higher cost from a -- less than $100,000 to $800,000.

Q. For the SCRIM?

A. For the SCRIM. Although the SCRIM, it has also some other things you can measure because you have lasers to measure microtexture and you have inertial system to look at the transversal and longitudinal profile of the road.

Q. You described about the ASTM locked-wheel tester and the ribbed tire being more sensitive to microtexture and the smooth tire having greater sensitivity as well to macrotexture. What about the grip tester and the SCRIM?

A. Yes. Most of them operate at the relatively low slip ratio, as you can see there in the picture on the left. Maybe we can go to the next slide in the presentation that is --

Q. Slide 7?

A. Yes. They operate at the lower slip so they are more sensitive to the microtexture. So it becomes quite important to measure also macrotexture to have the full spectrum of frictional properties throughout the whole braking process.

Q. In this slide, figure 6 from your report, the -- first, if I understand correctly, the red line, that's the same not-to-scale friction curve that we were talking about previously?

A. Hm-hmm.

Q. And then -- so what's it showing us? It's showing us where along that curve each of those three devices measure?

A. Correct. When you had the locked wheel -- you are on right with a hundred percent slip because the tire is completely locked, the wheel is completely locked, and the tire is sliding with respect to the pavement.

Then the grip tester is designed to be around the peak friction. Of course the peak friction will change depending on many other conditions has to do with the braking system and the vehicle and the vehicle -- but roughly again in general it goes close to this peak.

And then the SCRIM, because of the angle we're using, the 20 degrees, that translate into an approximate 34 percent slip in the longitudinal direction when we transform it into longitudinal friction.

And so you see this is on the same surface the numbers that you're going to get with a grip tester, the SCRIM, and the lock wheel are quite different as you see there. And again this is for the same level of friction, so you have to be careful when you try to interconvert from one to the other.

Q. And so directionally the -- between the three, if measured at the same pavement at the same speed, same thickness, water film and so forth, all other things being equal, those three devices will -- the grip tester will return a higher grip number derived from the coefficient of friction, then the SCRIM will deliver the sideways force number, and in turn will be higher than the locked-wheel tester skid number or friction number?

A. Correct. With the caveat that the slope of the curve to the right is dependent on the macrotexture, as we mentioned before. So you have very high macrotexture. The curve is flatter so you have the difference. It you have lower macrotexture the curve is steeper and you have more (indiscernible) in the device.

Q. Okay. And then on that point of macrotexture measurement at image 14 of the report, in section 1.2.3 it's titled "Macrotexture Measuring Technologies." And we've talked about the various friction measuring devices and in varying degrees being more sensitive to microtexture. So could you describe -- you've alluded to it a number of times, but what macrotexture is important for and what the measuring methods are?

A. Sure. And again macrotexture is important because that provides us with an indication on how fast friction decreases with slipping speed -- sorry, with the longitudinal slip or with the speed of the vehicle. So high microtexture, it can get a higher friction at high speeds, so is very important for high speed freeways and roadways in general. But the higher the speed the more relevant the microtexture becomes.

So historically we measure in an indirect way. We use things we call the sand patch or -- and it's -- that's where you get the specific volume of sand and you -- it's spread in a circle. So since you know the volume, if you measure the area of the circle and you divided -- the volume divided by the area give you kind of the average thickness of sand that you get on the surface, and that's what you called mean texture depth.

Q. The mean texture depth?

A. Yes.

Q. MTD?

A. MTD. And so this been used for many years. In our course we use grease instead of sand, and today we use glass beads for the same size, the standard that was (indiscernible) we use for years. And that's a good test. It's very time consuming and it's very operator-dependent because spreading the sand in a (indiscernible) is not as easy as it seems. And then again you have to be kneeling on the road for a while so from an operator safety point of view it's not a very practical test.

So over the years we switch to laser-based devices. So those devices use lasers that send the laser, the laser is reflected, and then you can get the actual profile of the pavement and then you can compute something called the mean profile depth that in a way is an estimate of the MTD that we used to measure, but it has ASTM standards to normalize how you do the calculations.

So you need the actual road profile, and then you get the peaks and based on that you look at the difference between the peaks and the mean depth, and then based on that, you estimate the mean profile depth. The higher the MTD the higher the macrotexture, and there is a very good correlation between MTD and MPD.

Q. Between MT as in Tom, D; and MP as in Peter, D?

A. Yeah.

Q. Mean profile depth and mean texture depth?

A. Yeah.

Q. And if you are using the sand patch test or the beads -- I guess by definition that's static -- you are just taking it in parts along whatever roadway that one is measuring as opposed to a continuous measurement?

A. Correct. And if you would use lasers, just use high frequency lasers, you can continually measure at the highway speed. So many of the friction tests today added a laser-based system to measure microtexture so they can get the two properties with one pass.

Q. If we go to image -- at the bottom of 14, "Operational Factors That Affect Friction Measurement." And there's -- don't expand that. It's okay. We're going to look at a slide as well. Thank you.

And so there's a number of things, some of which I think we've already talked about but we should cover them, and I think the next slide has some bullet points of the -- slide 8 covers the categories of operational factors that affect friction measurements.

So the first one I think we've already talked about is water film thickness, and the affect is that the more water the lower generally the friction measurements?

A. That is correct.

Q. And do the ASTM standards, do they direct the amount that -- the thickness of water film, the amount of water that should be used?

A. That is correct, and unfortunately it's not the same for all the devices so different devices use different thickness of water.

Q. So another area --

A. Yeah. You have to keep in mind.

Q. Right. And the next one

is the type and condition of tire. And if you could move on to image 15 in the report. But it's that worn tires are -- like smooth tires as you are describing are more sensitive to water film thickness?

A. That is correct, yes.

Q. I guess that's if your -- if you don't have treads on your tires, whether it's a testing tire or on your actual vehicle, it doesn't deal with water in the same way as with treads?

A. Yes. When you have a smooth tire the water has to drain through the channels provided by the macrotexture, so it's more sensitive in that sense.

Q. And then vehicle and sliding speeds, is that essentially the faster you go the lower the friction measurement?

A. Correct.

Q. And temperature. You indicate that the friction decreases as the tire temperature increases?

A. Hm-hmm.

Q. Right?

A. That is correct.

Q. And so everything else being equal, on a hot day you'll get a lower friction result, a lower friction reading than on a cool day?

A. Correct.

Q. Why is that?

A. This is for a couple of reasons. One is for the properties of the pavement and the tire. When you are talking about asphalt pavements, you will -- you have a viscoelastic material so the response of the material depends on the temperature. The colder the temperature, the harder the material. The same with the tire. It's -- the rubber properties changes with the temperature. In addition to that, the viscosity of the water that is in between the tire and the pavement --

Q. That's the viscosity of the water?

A. Correct.

Q. Sorry, go ahead.

A. Also changes with the temperatures. So you have the three elements that are interacted that are viscoelastic in a way, so their properties change with temperature so we have to be careful because, yes, they do respond different to different temperatures, even if it's the same exact material.

Q. In the first paragraph under "Temperature" it refers to the AASHTO standard for the SCRIM as stipulating a pavement temperature or recommending a pavement temperature between 5 and 15 degrees Celsius, actually sets out the recommended temperature range?

A. That is correct. Of course, you cannot test a very low temperatures because the water will freeze, so sub-zero temperatures are physically out of the question but they try to stay a little bit higher than that. That's why the five degrees C.

Q. And the British pendulum test and locked-wheel ASTM standards you've indicated don't recommend the temperature range but do indicate that one should report the temperature?

A. That is correct. In some states develop some temperature correction factors that they use to change for temperature, but not nationally-wide standard.

Q. Is the reporting

requirement or recording recommendation again for that reason, so that one can correct for temperature?

A. Yes.

Q. Okay.

A. You are aware if you have a very high value at low temperature that could be a potential case, even if you don't have a correction factor.

Q. Right. Because described directionally, the lower the temperature, the higher the friction reading. So it's a good piece of information to know if you're testing at a low temperature or particularly high temperature?

A. Correct.

Q. And last one, contaminants, perhaps is self-explanatory but I guess if you've got an oil patch on the road, that's something that will affect friction?

A. Exactly. Any type of -- even the -- circulation that --

Q. Sorry, was that gas --

A. Yeah, when it gets wet with the tire if there is long period without rain and you test friction, you wet the pavement, there's a lot of fines in there, you probably will get lower friction than if you test when the pavement has dry after a heavy downpour of rain?

Q. Once it dries, presumably?

A. Yeah.

Q. Cleans it but then dries?

A. Yeah.

Q. And then the bottom half of page 15 is the section on measuring aggregate polishing properties. I think this is what we were talking about before in answering the commissioner's question about the British pendulum test, and we spoke briefly about polished stone value testing.

So first, could you tell us what aggregate polishing is.

A. Yes. Different aggregate because of the composition of the aggregate from a mineralogically point of view from the mineral composed in the material, some of them they grade faster than others, they polish, they get weathered by the action of the tires, the dust and surface and all of that, so they lose the microtexture that is so important for friction faster than others. Some type of aggregates are more resistant to that degradation process that the traffic riding on the road produces.

So a lot of agencies they do require that the aggregate sources, in general -- it's not something you do on every project but you -- the core is where you get the aggregate that gets certified in a way that they provide good quality aggregate that doesn't polish with time. And there's two standard methods we use in North America for that; one is the polished stone value that is method imported from the UK where what you do is you glue aggregates on a metal coupon just for fixing them with an epoxy that you get the aggregate two different (indiscernible) and then you polish it with a wheel that goes for many hours continuously polishing, and then you test the British pendulum number after the polishing and that's what you report at the PSV. The higher the PSV the more -- the better quality the aggregate is with respect to polishing.

Q. So it's a -- I guess, that's a lab -- laboratory version of the field testing using the British pendulum test?

A. That is correct.

Q. But done after you polish the aggregate as you described by using the wheel. And that's a microtexture test; is that right?
A. That is correct.
Q. Because it's about the bumps, the asperities on the aggregate that's being tested. Am I right, then, this is a predictive test in the sense of you're sort of going for what will happen over time?
A. That is correct, yes. It tell you after many years of service what will be the friction that the aggregate would provide, of course as long as the polishing -- within the lab and in field.
Q. And with the distinction of the other types of tests we were talking about being which are measuring friction, actually at the time the test is done, and it is measuring the microtexture and the test is done but it's creating, put it this way, a future-looking prediction?
A. Correct.
Q. What about the Micro-Deval test?
A. It's an alternative test

that allow you to do the same. What you do is you place the aggregate in a cylinder, a metal cylinder, with water and you rotate it many, many, many times and then you measure how much of the aggregate you lose in terms of degradation. You field the results and then you weigh the aggregate before and after, and based on that you see how much the aggregate polish through this experiment.

Q. Go to image 16. This is when I talk about the interconversion of friction measurements and having discussed in some detail the different methods of friction measurement. Perhaps we could talk about how and if they can be compared to one another and interconverted.

Is it a fair summary to say that although there have been many efforts to compare or harmonize the measurements taken by different types of equipment that they haven't overall been terribly successful; is that fair?

A. That correct statement. And again, part of that is because of all the different factors that affect the measurement as we were talking before earlier, you have there in the slide on the right.

Q. There's a number of

studies that you refer to there, some of which I think you've been involved in. In the last paragraph of the section, it refers -- above the references it refers to two papers or studies about interconversion which mentions a De Leon, et al., from 2019 and 2017. Are those -- those are also projects that you were involved in; is that correct?

A. Those both project that I was lead investigator.

Q. And -- sorry, you were the PI on those?

A. Correct.

Q. And then coming first on it, does that mean Mr. De Leon was the principal author?

A. Correct, he was directing supervising a lot of the testing and called the paper, although many others that were involved as you see when you go to the full list.

Q. In the references?

A. Yes.

JUSTICE WILTON-SIEGEL: Mr. Lewis, I wonder if we could take a two-minute break?

MR. LEWIS: Absolutely.
JUSTICE WILTON-SIEGEL: Just one matter I have to deal with.
MR. LEWIS: Two minutes. We'll just wait. Perhaps if the registrar can mute everyone until the commissioner comes back. Thank you.
(DISCUSSION OFF THE RECORD)
JUSTICE WILTON-SIEGEL: Thank you.
MR. LEWIS: So I think when we left there, Dr. Flintsch, I was just at the bottom talking about the two De Leon papers that you were involved with about interconverting SCRIM measurements and lock-wheel testing, friction numbers using smooth and ribbed tires as the first one, and a similar one about equations to interconvert grip testers and lock-wheel tester measurements. And you finish the last sentence:
"However, the interconversions are not very accurate and may not apply to pavements not included in their development."
Could you explain what that means?
A. Sure. As I mentioned

before, the whole respect of properties of texture of the pavement, in particular the macrotexture of the pavements, may be different from one place to another or from even within the state, some regions, depending on the sources of the aggregate and all of that, it varies, so the interconversion depends so much on the macrotexture.

If you have different type of mixes or you use different type of aggregate, then those equations may not apply to other. If you go through the -- if I -- next slide in the slide deck.

Q. Slide 9?

A. Yes.

Q. The IFI, international friction index, which you refer to in I think the third paragraph of -- and fourth paragraph of your report on image 16.

A. That is correct. And again, in one of the report -- the first one listed there, the 2019 -- we did went to a series of -- facilities around the country get the very wide range of textures, both micro- and macrotexture, different type of surfaces. We were able to get the reasonable corrections, but again, with a caveat that good for the surfaces, we are not sure if they would work properly on other surface.

But what you could do to help in this conversion is account for the macrotexture, as I was saying before, and this international friction index with the sense if you look at the slip speed, and this would be the percentage of speed multiply by the speed of testing. So not the speed of what you're testing but that speed reduces the speed of the travel slide with respect to the pavement.

Q. Could you repeat that last point? The --

A. It's the speed of what the rubber in the tire is slipping with respect to the pavement.

Q. The speed of which the rubber is sliding in relation to the pavement.

A. Correct. So if you mention with any coupon that give you a specific value here, we call it the tender -- call it FRS, and then you use the texture to get the value of speed has to do with the slope of this, is not accurate. The slope is an explanation equation, but the idea is that the higher the texture, the flatter this curve will be. So if you have low macrotexture then the slope will be very steep. If you have high microtexture, the slope will be less so you can convert to a specific case that -- the international standard calls for 60 kilometres per hour. You could actually do it to any speed.

The idea here is to illustrate that this is not one number that you can use for all your surfaces. Depending on the macrotexture of the surface, your conversion will be different and it will follow this explanation train here.

Q. So you may be able to do it in a specific instance but not in the broader sense of saying a SCRIM number is equivalent to a crip number is equivalent to a lock wheel tester number?

A. Correct.

Q. And again, directionally -- regardless of the difficulties of correlation overall -- if I've understood you correctly to summarize a few of the things we've discussed, the grip tester will usually give a higher grip number than the SCRIM sideways-force number and higher than the lock-wheel tester skid number or friction number, that first thing?

A. Correct.

Q. And the higher the testing speed the lower the measured friction, whichever the device is used?

A. Correct.

Q. And as temperature raises, the friction measured will generally be less?

A. Correct.

Q. The next part of your report is about friction -- pavement friction management. And if we could go to image 19. Maybe if I could just go to image 10 of the -- slide 10 of the slide show just so we are on the same topic. Thank you.

So, broadly speaking, pavement friction management. You say in the first sentence:

"It's the various approaches that highway agencies use to specify and manage the frictional properties of pavements."

And you go on for the next couple of paragraphs to talk about some of the things you talked about at the outset about how friction is a factor not typically the only factor in rates of collision so forth.

Am I correct that friction management could be, broadly speaking, broken down to sort of a front end which involves engineering practices aimed at constructing pavements with adequate friction? And then in the second the approaches to take -- taken to detect and potentially take -- investigate and take action to deal with areas of pavements where low friction may be contributing to collision rates. Is that a fair breakdown?

A. Yes. That is definitely what it is. You decipher, (indiscernible) for friction and then you have to monitor it over time and act if necessary.

Q. In the fourth paragraph on that page, if you could call that out, you're referring to:

"Countries such as the UK, Australia, New Zealand and Germany establishing pavement friction management programs ... to provide a framework by which road engineers can monitor the condition of their networks and, based on objective evidence, make appropriate judgments regarding treating or resurfacing the road where required. These judgments balance the risk of a crash occurring with the cost and practicalities of providing adequate friction."

And then you go on to indicate that crashes may not be totally -- completely eliminated but an effective policy can reduce the risk. So just unpack it slightly.

The first thing is you really -- with a friction management program dealing in probabilities about reducing the overall risk of collisions occurring rather than any one particular collision; is that correct?

A. That is very correct. Again, you go back to all this factors that play a role in a crash regulation that you cannot say -- is very hard to say there was almost never this one cause of the crash; there's also a combination that lead to a collision.

Q. And then there's typically a cost benefit calculation in what one -- when an agency is prepared to do, the trade-offs between risks of crashes and the costs and practicalities of providing a friction that would reduce the collisions; is that right?

A. That's correct.

Q. And then at image 20, the next page, there's a discussion of the relationship between crashes and friction. I think you also have a slide that deals with this -- slide 11, that's correct -- which reproduces two of the figures but on different pages.

Could you discuss just directionally the relationship between crashes and friction levels?

A. Hm-hmm. Over the years -- and again some of these reports go back to the '60s and '70s when we start measuring crashes. The report I found there's statistical relationship between -- in the horizontal axis, you have the level of friction, and in the vertical axis you have the rate of wet crashes in the left, for example.

So you see there that when friction is low, the probability of you getting in a crash or when the pavement is wet is considerable higher than when your friction is high. Of course, you can see there, there is a lot of variability, I would say, but the trend is the higher the friction, the lower the amount of crashes and, again, you can model that mathematically using safety performance functions.

Q. You referred to the variability, the point there being it doesn't predict a particular event. It predicts overall the relationship between friction and collision rates?

A. Correct. You could also say in a way you're predicting the risk of getting into a collision.

Q. Just on the first chart -- maybe it's better to look at it on your report on the left; it's a little bigger and clearer. This is a 1973 study and on the bottom, it refers to on the x-axis, it refers to the skid number SN40. So coming back to what you described before, am I correct in understanding that the SN40, the skid number taken at 40 miles per hour?

A. That is correct. That is using a ribbed tire because at that time that's what they were using.

Q. So there was no S to put after it, or R, because it was assumed it was a ribbed tire at the time?

A. Correct.

Q. And then on the y-axis, as you indicated, it's -- are the accident rate -- the wet surface accident rate per million vehicle miles?

A. A hundred million.

Q. A hundred million, yes. Sorry.

If you could reduce that, please.

And then in figure 9 --

JUSTICE WILTON-SIEGEL: Can I ask why are there are two lines? You've performed -- the analysis was performed on two sets of data?

THE WITNESS: Yes. The two lines, one is for traffic between less than 3,000 vehicles and more than the 3,000 vehicles. Is just high volume versus low volume --

JUSTICE WILTON-SIEGEL: That's what I thought it was saying but I wanted to clarify; hence, the different symbols for the axis.

THE WITNESS: Correct.

BY MR. LEWIS:

Q. The second figure, figure 9, which is from the next page of your report as well, this is from a very recent study and is that one that you were involved in?

A. Yes, this is part of Rosemary McCarthy's dissertation that I supervised, and in this case we collected data from various states, parts of several project we have over the last decade, and what we did was look at the data in relation (video freezes).

Q. We have a bit of a glitch. Probably too good to be true.

Dr. Flintsch, you glitched out there so if I could ask you -- it was in response to my question about the 2021 study and that graph and you mentioned Rose McCarthy and then you -- supervising her dissertation. Perhaps you could start at that point.

A. Okay. Yes, I'm sorry about that. Yes. What he did he got information from several reports and used that to develop the statistical relationship between the number of potential crashes and the side force number -- sorry, side force friction number measure with the SCRIM, and the way I presented it in that chart is using a reference of 60 as a value how much the crashes will increase. What he did find is that both wet and dry crashes increase when the friction goes down, but of course they increase is more pronounced when you had the pavement is wet. So if you go from 60 to 20 --

Q. That's moving left across the x-axis?

A. Yes. So 20 is a very low value in terms of friction. You may get 50 percent more dry crashes and almost more than double the amount of wet crashes.

Q. The SFN on the x-axis, that is the sideways-force number from the SCRIM, right?

A. That is correct. And that's at 40 miles per hour.

Q. 40 miles per hour, or 65 kilometres an hour?

A. Correct. Again, this is just provided as an illustration because it's based on sample of data but there are other studies that have found that also some of them by other students also by other researchers in other universities in the last decade mostly.

MR. LEWIS: I think this would be a good time for the morning break. It's five minutes before but I was about to move on to another topic, if that works.

JUSTICE WILTON-SIEGEL: That's fine. We'll take 15-minute break. Is that what is proposed, Mr. Lewis?

MR. LEWIS: That's right. I would ask everyone to be back -- it's 11:25, and to keep things moving we would ask everybody to be back and ready to go at 11:40, in 15 minutes.

Dr. Flintsch, and anyone else, you can mute, and your screen, and turn off the video, but if everyone can be back and ready to go at 40. Thank you.

--- Recess taken at 11:25 a.m.

--- Upon resuming at 11:39 a.m.

MR. LEWIS: It's 11:40. I should probably apologize to everyone. Rather than asking the registrar to send everyone to their respective breakout rooms, I didn't do that and so if anyone wanted to speak to another, perhaps they were unable to so in their breakout rooms.

Registrar, in the future if we

do a formal break or lunch, if you could send everyone to their respective breakout rooms to join and then bring back in from there when we resume, I would appreciate it. Thank you.

THE REGISTRAR: Understood. Thank you, Counsel.

MR. LEWIS: Commissioner, may I proceed?

JUSTICE WILTON-SIEGEL: Please do.

BY MR. LEWIS:

Q. Call up images 21 and 22 for -- in the report. This is a section on -- brief section on designing for friction, and I just had a few questions about that. It moves on to the next page, 22. If we could have those both up.

I wonder if just briefly you could explain the effect of the pavement mix design and aggregate selection on microtexture and macrotexture as you outline it in there.

A. Okay. The microtexture part has lot to do with the -- as we discussed before, with the polishing properties of the aggregate. So to provide good microtexture typically what we do is -- all agents do is to specify some sources of aggregate that are appropriate for use in the surface of the pavement, and so a lot of this has to do with the way are characteristics of that.

Of course, to get the macrotexture it's a little bit harder to do, and that's something that we do (indiscernible)...

(DISCUSSION OFF THE RECORD)

BY MR. LEWIS:

Q. We just left off with -- Dr. Flintsch, you were about to talk about the microtexture is a little more difficult, I think you were saying.

A. I put a reminder and the headphone cancelled the noise. My fault.

Q. Mystery solved.

A. The microtexture part of the friction is typically controlled through proper aggregate selection so using tests like the PSV we mentioned before. So typically the most highway agencies will restrict the sources of aggregate that can be used in the surface.

Then for the macrotexture part, that has a lot to with the maximum size of the aggregate, and that is something where I don't think we completely understand these properties. So there's been studies in the past with something we can't control very well yet.

Q. So you use the term with respect to macrotexture in your report, that the gradation and aggregate size governs the macrotexture properties. What's the difference between gradation and size?

A. Okay. The aggregate size typically refer to the maximum size of the rock that used in the mix. For example, at 12-and-a-half millimetre mix means you won't find rocks that are bigger than that size and partial dimension in all direction, so at least the majority of aggregate is smaller than that size.

On the other hand, the gradation has to do with the distribution of sizes. So we call continuous gradation is gradation where the bigger stones, little spaces that are filled by smaller stones and then they get filled by -- so a dense mix will be a mix that has all sizes and then we have mixes that we need some sizes like calculated mixes.

Q. Gradation testing is

testing the distribution of sizes of aggregate within the mix; is that right?

A. Correct, correct.

Q. I gather from your part that it's the course aggregates, the large aggregates that govern the frictional qualities in the microtexture, is that right, in asphalt pavements?

A. Yes, for the microtexture it is. For the macrotexture, the percentage value, it probably has more affect but both have an affect.

Q. Image 22, we can just pull up one page from the report. So when you talk about friction demand, which this section 2.3 is about, could you describe the concept? What is friction demand?

A. Of course not all the vehicles need the same type of friction under all circumstances, but in general if you look at the whole family vehicles, different type of roadways and different particular locations along the roadways require different friction, so when we refer to friction demand is the level of friction we need to provide to the vehicle to safely accelerate, brake, and steer the vehicle along the road. So the amount of friction that you need in straight sections with very good geometric design -- when I mean with geometric design for a freeway, for a limited access highway -- will be different than the friction demand you have in a secondary road with a lot of curves. So, typically, the more curves, the more intersections you have, the more conflict between vehicles, the higher the demand that you need to provide for the vehicles to use that facility safely.

Q. And so I take it high traffic areas typically have a greater friction demand than low traffic areas; is that right?

A. That is correct. Also depend on the posted speed.

Q. On the?

A. On the posted speed.

Q. On the posted speed, of course. Being the faster it goes, the higher the friction demand?

A. In general, yes.

Q. And you indicate that the UK has led in defining friction demand categories. And we'll look more closely at the friction demand charts, the categories with the friction investigatory levels in a moment, but more generally, could you describe how in the UK they set demand levels and -- yeah.

A. What they done in the UK is similar to what we done here in the US much more recently, but the idea is what they look at the statistical relationships between the crashes or collisions and the friction level for different type of facilitates, and within this different type of facilitates they separate what we call events, and those events are like sharp curves, for example, with the radius of less than 500 metres, very steeper downhills that, of course, because of the downhill requirement friction and approaches to intersections, roundabout, pedestrian crossing, et cetera, any place where there's a high probability of the vehicle having to change their speed and eventually break is when you consider that you need high level of friction.

Q. And then I understand that investigatory levels, which we'll describe, are assigned to each friction demand category?

A. Yes. Based on that is

the (indiscernible) analysis you can define levels of friction where you see the trains (ph) is smoke (indiscernible) below that number, so you could say investigatory levels where you say, well, below this number I probably should look carefully that particular road section because it may require a friction improvement because some of the crashes that are happening, if they really are happening, could be due to the level of friction being below what its safety operation would demand.

Q. So if we go to the next image at 24. If I understand it, an investigatory level that is the threshold, whether it's in grip number or friction number or sideways force number at which an investigation is stipulated, that ought to take place to determine if there is an issue of friction?

A. That is correct.

Q. That's an investigatory level. And then from that investigation whether some countermeasure or remedial activity ought to take place or not, depending on the results of the investigation; is that right?

A. That is correct.

Q. And I understand from -- if we go back to image 22, there's -- you have a discussion at the bottom of 22 going onto 23 about the 2008 AASHTO Guide for Pavement Friction, and that it recommends highway agencies establish investigatory levels and intervention levels.

Does the AASHTO guide prescribe what those investigatory levels should be or just that they should be established?

A. No. They do not prescribe a specific level but what they provide is three different methods to define those based on the relationship between crashes and frictions and also based on the changing friction over time for a specific section.

Q. And I think we'll deal with that, the three specific things, later on but I just wanted to cover that particular point.

Right at the bottom of image 22 you indicate that recent proposed revisions to the guide, the AASHTO guide, recommend eliminating use of intervention levels because agencies are unlikely to trigger treatments without a detailed project investigation.

So an intervention level in a

guideline, I understand it to be where actual remedial action is recommended or required once the friction level drops to whatever the assigned number is; is that right?

A. That is correct. That's -- actually, that's when if you have the definition that the guide has for intervention level is with, yes, something is required to be done in that section of road; although, it could be just posting a sign saying slippery when wet; it doesn't mean it has to correct the friction but they have to do something at that particular section of road.

However, as we said before, lot of the decisions are based on a statistical analysis, so really to have a mass do threshold (ph) difference in the reasonable, so that's why in some of the proposed revisions that have been at least approved by the sub committee that deal with in AASHTO, that intervention level has been eliminated and we just talk about investigatory levels where you should look carefully and see if it's an intervention is needed or not.

Q. The idea being that the investigation will determine whether or not something is required and what that is?

A. Exactly. That's more aligned with practice in the agencies. Typically, we do kind of a screening at the network level and then when we identify possible interventions at all level from an overlaying because it's a lot of potholes to safety correction as we talking here, and then it goes through a more detailed investigation to define the actual list of project that we carry out every year.

Q. Sorry, the AASHTO guide pavement friction, that is being -- I gather what you said -- that amendments have been proposed and recommended and I think accepted but it hasn't been publish yet; is that correct?

A. That is correct. It's been reviewed by the sub committee responsible, it has to go to a full AASHTO ballot and then it goes into the standard this summer, hopefully.

Q. And then back to the UK investigatory levels. At page 23 -- sorry, 24, there's a table and this is the current -- as I understand it, UK friction demand categories and investigatory levels chart; is that right?

A. That is correct.

Q. And they have changed somewhat over time, I understand, from your report; is that correct?

A. That's correct, and some -- based on their own more data and more statistical analysis that became available.

Q. And this is a 2021 chart?

A. Yes.

Q. And in your report on that page, I think you had indicated that there are -- previously the standards were in 2004 and 2015; is that right?

A. That is correct.

Q. Is the current standards -- the new one materially different from those?

A. No. The values are more or less the same. The notes that clarify how to use these specific conditions have been evolved over time a little bit and the presentation also changed a little bit, but fundamentally the values have been the same since the last couple of revisions.

Q. So substantively the investigatory levels and the demand categories are the same but the explanatory notes and explanations and so forth, those things have been refined but it's substantively the same?

A. Correct.

Q. This is -- these investigatory levels are SCRIM numbers, correct?

A. Yes.

Q. CSC?

A. That is correct. And, again, this is in the UK, the shot (ph) numbers seasonally accounting for the measurements of different temperatures, and also they adjusted because of the -- over the years, the rubber component they use in the tire, it changed, so they multiply by a factor of two so these values are a little bit different from what we would measure here in the US, for example.

Q. To be clear, these are SCRIM numbers, not lock wheel or grip tester?

A. Correct. And they are not numbers. They are actual coefficient of friction as you see there, they are decimals.

Q. Right. So .35 or .4, instead of 35 or 40?

A. Correct.

Q. And --

A. The other -- this all measure at 50 kilometres per hour too.

Q. Right. And is that different now than in the U.S.? Is there a standard now in the U.S. at a different speed?

A. I lost you for a second.

Q. Is there a different speed standard in the U.S. now?

A. Yes. The tender that's been adapted by AASHTO is to measure at 40 miles per hour just to be consistent with local measurements that were done over the years that were also 40 miles per hour.

Q. So different than the UK standard speed but the same as what has been typically done following the ASTM lock wheel standard at 40 miles per hour?

A. Correct.

Q. And the key beneath the chart does set out some guidance as to which investigatory level should be used, and I understand that ST is the -- that's the general one that should be used?

A. Correct.

Q. And if there's some special lower risk circumstances -- thank you -- the LR is a lower one that can be used in lower risk situations?

A. Correct. Again, you see a little bit generic but when you have no traffic or over the years don't see many crashes, then you can reduce it, the level a little bit.

Q. When you've established as a risk probability is lower, generally speaking?

A. Correct.

Q. And then if we could reduce that and pull up slide 12 in the slide show?

A. Maybe before we move on, just a comment that this is relevant. We mention it, but maybe look here, you see that in the events where you have the more interaction between the vehicles the investigatory levels are higher than when you are in a straight road with no control axis, for example.

Q. Right. So -- sorry, really I did skip over that. If you've got a -- it's one thing if you're on a motorway which has the lowest ST, being the general range of investigatory level at I'll say 35 -- if that's okay instead of coefficient -- at 35. But if you go down to G2, row G2, if there's a gradient greater than 10 degrees longer than 50 metres, then that increases the investigatory level to 50 or 55. There's a range.

A. Yeah, correct.

Q. And then roundabouts, that's more typically a British thing than at least in Canada, although they exist -- as well has a higher, I suppose understandably, investigatory level. And bend radius as well, under 500 metres.

Do you know what the distinction is between a motorway and a carriageway in these circumstances?

A. Motorways control access. The other ones are two lanes and four-lane highways but they don't have control access, or at least it's not fully control access.

JUSTICE WILTON-SIEGEL: Is the difference between the M highways and the other two- and four-lane highways the older ones?

THE WITNESS: Correct.

JUSTICE WILTON-SIEGEL: Okay, that's what I would have thought.

THE WITNESS: The motorways will be the equivalent to the interstate highways here in the US.

BY MR. LEWIS:

Q. So then if we can -- Dr. Flintsch, it would make sense to expand the slide here so that we can see it better.

A. Hm-hmm.

Q. So this is a -- thank you. This is table 1 is what we were just looking at. Table 2, on the right, is a 2005 chart and -- which appears in the report on page 25. And can you describe what we're looking at here?

A. The two tables are the equivalent in a way but the responsibility for managing the highways in the UK had changed over time. It was divided by the different countries they compose, the Great Britain, and then it's now been integrated into a national system in a way. So over the years they have different specifications.

So for many years they have a specifications for the UK PMS, meaning pay (sic) management system, that the different regions had to propose. So if you see the tables there, the bottom part of the tables are similar where you have ST, you have a dark gray, where you have LR, meaning the alternative values, you have light gray. This is certain changes. The notes will be different if you go into the details. But for some local municipalities and local regions where they didn't have the SCRIM or they have roads where they have to drive with the SCRIM but there's a big truck, they provide alternative grip numbers for these.

Again, this is not the national standard. This is just a way to put these to the regions, and what they did is they use a factor of .85 to convert from SCRIM numbers to grip numbers. And in 2005, they have this in more recent specification going through the same website just from maybe a year ago or so where they talk about these that the interconversion could be done but not necessarily very accurate. That's as we mentioned before.

Q. So on the table 2 -- again taken from your report -- it's showing a correlation between the SSE, which is the SCRIM number, and then the grip number immediately below it at -- and then applied to each of the investigatory levels. And that's at a conversion factor of .85?

A. And again, that correction factor is a correction factor that was developed statistically and not super accurate but it is the best I could find. This number change a little bit in other reports later on.

Q. And then if we could go back, then, to image 24 in your report. In the paragraph at the bottom, the second last paragraph starting more recently, I think you're indicating that it's been replaced and this is what you're referring to about the current website uses a different conversion factor, and this is .89, the new conversion factor?

A. Exactly. And what they did is the TRL, the other comparison between the two equipment with more surfaces and more testing and adjusted the coefficient, again, that's reflecting of what I said before, that the comparison depend on which surface you use to determine that conversion factor.

Q. And then in that section

last paragraph, second sentence says:

"Furthermore, the site indicated that the correlation applies only," quotes, "to the specific surface types assessed as part of PPR 497. If a grip tester is used to monitor a network then appropriate investigator levels should be calculated for the grip tester results rather than converting the grip tester data into SC --" SCRIM I take it "-- data and using the investigatory levels defined for sideways-force devices."

What does that mean?

A. It means that what I said before, that these correlations are kind of approximate, so if you are going to use (indiscernible) regular basis to monitor your system, you should do the statistical analysis that was done for the SCRIM to define if these are the actual values that should be used in (indiscernible).

Q. If you are going to be using this in depth for your network, come up with your own investigator levels for the grip tester specifically?

A. Correct.

Q. I was going to move on to Australia and New Zealand, but I appreciate there's a lot of information there so, Mr. Commissioner, if you have any questions before I move on?

JUSTICE WILTON-SIEGEL: No, I don't. Thank you.

BY MR. LEWIS:

Q. So at image 24 -- that's, Registrar, 25 -- 25 and I guess 26 if you could pull them both up. Starts with Australia in section 2.4.2, and then on the next page, New Zealand, 2.4.3.

As I understand it, in summary, both Australia and New Zealand have guidelines for friction demand categories and investigatory levels just as a general proposition; is that right?

A. Correct, yes.

Q. And are they, generally speaking, similar to the UK approach?

A. Yes, they mostly based on the UK approach but they put them some additional data collection and -- for example, in Australia for some more woodland (ph) type of facilities, they do testing at the lower speed; they do it at 20 kilometres per hour instead of 50, bottom of the table.

Q. On image 26, the site categories in table 3, site categories 6 and 7 for curves with a tight radius of equal to or under 100 metres for roundabouts, they test at 20 kilometres an hour rather than 50?

A. Yeah. Those numbers are a little bit different than the others.

Q. Right. Again, directionally, it would be a higher SCRIM number that they would get than from the results at 50 kilometres an hour?

A. Correct.

Q. And they also seem to have a different -- in category 2, there's a curves with a tight radius under 250 -- 250 metres in gradients greater than 5 percent and greater than 5 metres long. That is different than I think for the UK standard?

A. Yes. The UK is 500 metres. I believe the original standard for the UK may have been 250 but been changed with more data became available.

Q. I think you indicated that was the carriageway -- referred to the carriageways as opposed to motorways.

A. Right.

Q. And then New Zealand also uses the SCRIM?

A. Yes, and I use the similar table if you go to the next page, 27, I believe --

Q. Keep 26 and 27 up, please. Top of 27 is the New Zealand standard and I see it has a again curve requirements also. What speed is it done at? I don't think it says it there.

A. It doesn't say but I believe it's 50 kilometres per hour, the standard speed for SCRIM.

Q. In addition, they have a macrotexture requirement in New Zealand; is that right?

A. That is correct, and that's in the next page, table 28.

Q. If you could go to there, please.

A. In that case, they do

have an intervention level here where they do require corrections in friction if the macrotexture is below a specific value.

Q. An actual intervention level as opposed --

(Speaker overlap)

Q. -- as opposed to investigatory level?

A. Yeah. And they call it TLM.

Q. TLM is the intervention level?

A. Yes, correct.

Q. ILM is the investigator level. Macrotexture is I guess the M?

A. Correct.

Q. What is that describing in the macrotexture requirements when it's 0.4, 0.3?

A. That's the MPD, the mean profile depth in millimetres.

Q. So that's not done by mean profile depth, that's done by profiling machine rather than say the sand patch or bead method?

A. Correct, it's a laser-based system.

Q. Laser based, right.

Immediately below there, there's section 2.4.4 on Canada, and you begin with:

"I'm unaware of any published provincial or national standards in Canada respecting highway friction investigatory or intervention levels in the provinces who developed different approaches to manage friction."

And is that -- that is your understanding?

A. Correct. I based on the literature -- consultations with some colleagues.

Q. And, Commissioner, as I indicated yesterday and from the agreed summary of pavement friction practices in Canada, introduced a number of individuals from the Ministry of Transportation of Ontario will be called to testify as to MTO practice and policy respecting highway friction management in Ontario, including the MTO's use of approved aggregate sources and the use of the ASTM locked-wheel tester and application of results from that testing.

I just want to -- that document I had a couple of questions. This is Exhibit 11, RHV932.

Q. You've reviewed this document, Dr. Flintsch?

A. Yes, I have reviewed it and I agree with it. At least, again, I not fully familiar with the practice in Canada but this is consistent with what I found in the literature.

Q. That's all I wanted to ask, except for one particular item, image 2.

In the last paragraph there it talks about a paper by Mr. Abd El Halim in 2010, and are you familiar with Mr. Abd El Halim?

A. Yes, I familiar with his work and I actually had to review his dissertation which included some of the work mentioned here because I was appointed as external examiner for his dissertation and participated in his defence.

Q. For his PhD dissertation defence?

A. Yes, correct.

Q. Small world amongst pavement friction experts.

A. He did his PhD at

University of Waterloo.

Q. Thank you. You can take that down, thank you.

If we go back to the report, image 28. This is the section on pavement friction management in the United States, some of which I think we covered as we've gone along but first question is: Is it a common practice in the US to use investigatory level thresholds?

A. Not yet. Most agencies have some policies, but typically they use maybe a value, and it's just not a former value, mostly like a recommended value that they use. So some do have some values and those values originally were defined using a locked-wheel tester and only considering the -- mostly consider the relationship between wet and dry crashes. So the idea was looking at the values where the percentage of wet crashes start to be higher.

So for many years there was something we call wet accident reduction programs. The state had to define and to receive the fund for doing the safety improvement and idea to look at places where they have very high percentage of wet crashes or more than a specific number of crashes, and in those cases they would look at the friction and define the friction (video freezes).

Q. At the bottom of the page 28 indicates:

"The majority of agencies use only one threshold which does not discriminate the roadway way or site type."

So on demand categories it's one number and based on the locked-wheel tester, for example; is that right?

A. That is correct. And then the AASHTO guide, they introduce the concept of investigatory and intervention levels at that time and then that -- some state try to do it but I don't think anyone has appreciably adopted them; although some did the analysis and some did -- listed there in the references.

Q. You mention about New York state. Department of Transportation in New York uses the locked-wheel friction tester and if a section -- at the top of image 29 -- if a section has one or more FN40R readings less than 32, it is recommended for treatment. So that's a friction number using the locked-wheel tester at 40 miles an hour, or 65 kilometres per hour, using a ribbed tire; is that right?

A. That's correct.

Q. And then you indicate there are some typical restoration treatments of an asphalt concrete overlay using non-carbonate aggregates, or a thin microsurfacing. We'll talk about remedial things a little bit later because you have a separate section on that.

You referred to, again, the AASHTO guide and talked about that earlier and there being three methods suggested for establishing investigatory and intervention levels. More recently, just to be investigatory levels, I gather. But in the 2008 guide you set those out on page 29.

I think you said before that the AASHTO guide doesn't prescribe what those levels should be; it prescribed how the different methods on establishing the levels; is that right?

A. Correct.

Q. On the next page, image 30, in the second full paragraph beginning "Furthermore," you've spoken of a recent 2021 U.S. Federal Highway Administration study. Do I understand correctly this is one you were involved in?

A. Yes. This is -- well, we are still involved in because we still working on this but the one of the attached was to review the AASHTO guide and provide some recommended approach for --

Q. So that goes to part of the recommendations you talked about regarding eliminating the intervention levels; is that right?

A. Yes, that's one of them and this also more of a systematic approach to analyze the friction level using the benefit cost analysis.

Q. And is that in the next paragraph where it talks about the methodology proposed, which has been included in the guide?

A. Correct.

Q. And we give a number of items there and perhaps if you could describe it and then could you indicate -- in the closing paragraph, there's that methodology has been implemented enhanced by Virginia department of transport on a pilot program. Is that also one you're involved in?

A. Yes, correct. In the third place of implementation now for Virginia DOT.
Q. For the Virginia DOT, department of transport?
A. Correct.
Q. So if you could just briefly describe --
A. Sure. What the methodology proposed and, actually the methodology, you're right, it was developed in a previous study that where we were tasked with demonstrate how to apply the AASHTO guide for -- to develop this investigatory levels but we propose an alternative approach instead and the idea is we were likely (video freezes) any slight improvement --
Q. Dr. Flintsch, we had just a slight glitch. If you could go back about 10 seconds.
A. I was saying that we were tasked with the demonstrate the application of the AASHTO guide but one of the conclusions we -- one of the -- we proposed an alternative approach that uses the safety analysis approach prescribe by the

AASHTO highway safety manual where you base the decisions that even (ph) based on systematic regulation analysis, the relationship between crashes, and in this case friction; in other case would be the presence of the different safety features on the road. So what we propose is to do an entry level friction macrotexture and geometric data.

Q. And what?

A. Geometric data.

Collected again from the network and link that with the crashes or collisions. Then we propose to adopt the friction demand categories as following a scheme similar, not exactly the same like the UK, a little simpler maybe (indiscernible), then develop statistical models that are called safety performance functions that related -- predicted number of crashes is a predictive approach based on the values element, characteristic growth from friction, macrotexture, curvature, longitudinal slopes, et cetera, and then we can identify sections below a specific value and friction and then look at how many crashes could be reduced using the mathematical formula that we obtained with the statistical analysis, and based on that do a benefit cost analysis and -- of course, you had to assign an economic value to the crash based on how many person die, how much damage of the vehicle, et cetera, and then using that you can do a benefit cost analysis where you identify the sections that will result in the maximum reduction of crashes because of that friction improvement. For each dollar I would say a friction improvement invested in that section.

Q. So it's not just a safety analysis, strictly speaking, it's also a how much it's going to cost to reduce accidents by -- collisions by a projected amount?

A. Yes.

Q. I think it indicates on image 31 that the site predicted a 20 percent reduction in crashes approximately; is that right?

A. Yes, if you were to (video freezes).

Q. Again, you glitched out slightly again. It was just after I asked the question.

A. Yes, for -- at least for the network that we analyze, and again this not a nationwide study, it was few samples from a few state. We could go up to 20 percent of crash reduction if we were to treat all the sections where there was a cost-effective or impact of improving friction.

Q. On the topic of methods for improving low pavement friction. At image 31, immediately below there, is -- part of a pavement friction management program is once it's been decided that there may be a low friction problem that needs to be addressed and if it's going to be addressed by means other than signage or posted speed, things like that, then there are a number of different methods for remediating the frictional qualities of the pavement; is that right?

A. Correct.

Q. And I guess the first one that you indicate there is the traditional way is to mill and pave. You remove the surface layer and repave it.

A. With a new layer with better friction.

Q. And then there's a number of different options listed at images 31 to 32.

Registrar, if you could keep 31 and 32 up.

A. This is just a sample of the most common treatments.

Q. And there are quite a number of them. There seems to be similarity to some of them, at least to laypersons; is that fair?

A. That's fair, and really there's one treatment that is, I'll say, site treatment; it's high friction surface treatment. This is specifically design for (skipped audio) improvement and provide very high friction of microtexture. That's what we call a high friction surface treatment, HFST, this is the knowledge developed in the UK where they do, like, apply an epoxy material on the surface of the pavement and then imbed the aggregate, imbed half the aggregate, get this -- the pavement by this very high quality adhesive material that's typically polymeric resin, like a two-component epoxy material.

And then you -- again, you spread aggregate, one layer of aggregate. Again, you get the surface there with the aggregate that contains friction very well, doesn't get polished, and then provides very high friction and macrotexture values. It's expensive but it provides again very high values for potentially very high reductions in crashes because this is statistical mathematical relationship that we can establish between crashes and friction.

Q. And given the cost is typically something that would be used for repaving spot sections or large sections of roadway?

A. Used mostly for spot section. For example, the UK, they use a lot approaching the roundabouts. Here in the U.S. we have a program to put these in sharp curves where there's a lot of crashes. Approaches to intersections, we have a very successful application in Florida, for example, as part of the study I was mentioning before.

Q. In image 32, microsurfacing, which referred to as being a common preservation for high volume, high speed roadways. Describe that one.

A. Yes. This is a treatment where you mix an emulsion, a very high quality emulsion, with a well-graded aggregate and create like a thin layer of asphalt, but it's not done in a hot mix, in a hot plan, but is rather done with an emulsion that is a mix of asphalt and water that is....and then it provides general good friction in macrotexture, although this is not necessarily the case. In some places if you don't design it properly, you could have also low friction, and in particular you can have low microtexture whether it be a problem when you have high posted speed on the freeways and other roadways.

Q. If I understand you correctly, it isn't necessarily that that's the case, but you have to be the proper application in order to ensure you have -- that it adds to the frictional qualities?

A. Correct. Some of them have worked very well, others provided worse conditions, sometimes the ones that were trying to correct.

Q. And then the last one, shotblasting, which is subcategory skidabrading, if you could discuss that.

A. Yes. This is like a

short term type of friction restoration treatment. What you do is you apply steel bolts at the high speed, you project it to the surface so it kind of roughen the surface and increases the friction and used quite a bit in runways because it help you remove rubber and oil deposits, so kind of breaking a little bit the aggregate on the surface and peeling the asphalt and restoring -- it is a solution that have been (indiscernible). It's not used a lot in the U.S. and still a little bit experimental but it's used more in the last few years. And skidabrading is just special way of doing this with a special machine that is patented.

Q. Okay.

A. This type of shotblasting technology.

Q. Short -- tends to be a shorter term solution; is that right?

A. Yes.

Q. If we can move on to section 3 of your report, at image 36 to begin with. This is about stone-matrix asphalt or stone-mastic asphalt, moving on from specifically friction issues.

Can you tell me a little bit about the history of SMA and when it was introduced in various locations?

A. I think I mentioned at some point when you look at the degradation of the aggregate, you have what we call dense-graded mixes where you have a continuous distribution of sizes of the stones that used in the mix, and then we have a familiar -- special family of mixes that call gap-graded where some of the size are missing.

Q. Sorry, that's gap-graded?

A. Correct. And --

JUSTICE WILTON-SIEGEL: The first category of mixes you referred to as --

THE WITNESS: We can hear you.

JUSTICE WILTON-SIEGEL: You referred to the first category of mixes as dense-graded?

THE WITNESS: That's correct.

MR. LEWIS: I interrupted, Mr. Commissioner. Please, go ahead.

JUSTICE WILTON-SIEGEL: No, go ahead.

BY MR. LEWIS:

Q. So dense-graded and gap-graded?

A. Yes. So one is special case of gap-graded mix is the SMA. It was originally available in Germany and what they do is they remove some of the fines. So if you go to the picture at the bottom there of the page, you see that the one of the left, there is much more contact between the coarse particles of the aggregate compare with a typical hot mix asphalt, the dense-graded mixes where you have kind of more uniform distribution of sizes where smaller particles fill the voids and then smaller particles fill the voids and so on.

Q. You referred to "fines." By that I understand you mean the small aggregates, not the course aggregates?

A. Exactly, the smaller aggregate. You see there some sizes missing. You still have some fines but not as much as we have onto mix on the right.

So to compensate for these lack of some size, what we do is we have a very high quality binder, typically polymer modified binder, and we add more of that binder to get the very thick layer of asphalt cover in each of the aggregate, and that's very important for durability in terms of cracking. The thicker the binder, thickness, the longer it will take for the mix to crack, but also because you have a lot of aggregate interlock as you see there. We also have a lot of restrictions of the shape of the aggregate in this mixes to be kind of critical to have a lot of interlock between the aggregate. So you also have very good resistant to rutting, so it's a mix that is designed for durability in terms of delaying rotting and cracking and therefore enhancing the performance of the mix.

Q. And you indicate in paragraph 3 -- bear with me for one moment. In the third paragraph you refer to the mixture gains most of it strength from the stone-on-stone aggregate skeleton. Is that what you were just referring to?

A. Correct.

Q. As well in that paragraph you're referring to the SMA containing asphalt, AC, which is asphalt cement; is that right?

A. Correct.

Q. Filler and stabilizing

agent such as fibers and/or asphalt modifiers. How does that differ from conventional dense-graded mixes?

A. Typically -- well, more conventional mixes they use (indiscernible) binders so -- high volume roads sometimes we use also modified binder. When I talk about modified binder is an asphalt where I -- well, they add polymers to enhance the properties, it cause more expensive asphalt but also has better properties through a wider range of temperatures to control the distress associated with the deterioration of asphalt mixes.

So you have a high quality aggregate and you have a high quality asphalt. In addition to that, we typically use fibers and those fibers would allow us to add -- provide more surface area so we can have more binder, more in this case polymer modified by -- to the mix.

Q. And you indicated it's typically -- hope certainly to be more durable, so longer lasting than other surface course mixes?

A. Yes, they last longer and cost a little bit more but, in general, the study showed that the cost benefit of the amount of life

extension is -- justifies the extra cost.
Q. And if we go to image 37. It indicates in the first paragraph that in Virginia several districts use SMA on most of their interstate highways?
A. That is correct.
Q. And then indicating that some -- more generally, that some states reported significant increases in surface life due to SMA use but not in all states; is that right?
A. That is correct.
Q. What's the Virginia experience been?
A. It's very good. I believe -- there is report done in 2007 that show again that there was more durability and that justified again the extra cost.
Q. Justified the extra cost?
A. Yes, correct.
Q. And in 3.2, under "SMA Functional Properties" on the same page there's a reference to noise reduction qualities. Is that -- I think it says 2 decibels?
A. Yes.
Q. Is that a known quality

of SMA?

A. Yes. And in some cases, it provides some noise reduction. This not allowed -- to be a significant reduction should be at least 3 decibel but still quieter than regular -- in this particular study that was done under control conditions there at the National Centre for Asphalt Technology Test Track in Alabama, they also find high friction and good macrotexture there.

Q. That's the NCAT Test Track that you are referring to?

A. Hm-hmm.

Q. Right. And it seems from reading -- if you can un-highlight that, please, registrar -- on page 37 and onto the next page, 38, if we can pull them both up. There are a number of studies that you refer to about frictional qualities of SMA, and I will park for a moment, the early age low friction issue, and come back to that at the end.

Apart from that, am I reading this correctly that the evidence is a bit equivocal on the frictional qualities of SMA as a general category but whether it gives improved or not improved frictional qualities; is that fair?

A. That's a fair statement. Some study show better performance like the one they did under control conditions and some state do not, and I think it had to do with the source of the aggregate. It's not the matter of if it's SMA or -- mixes. Depends what type of aggregate you use in the mix.

Q. Not the category -- it's not the overall category of mix, whatever that is. It's what goes into that mix; is that right?

A. That is correct.

Q. And there was at slide 16 -- this is from your figure 14 from a study again in Virginia, it's I think marked as De Leon, et al., 2021. Is that another one -- one of the ones we referred to you've been involved with?

A. Yes. One of the reports -- well, it's their report we did for the first implementation of the methodology in Virginia. We implemented for what Virginia DOT calls corridors of stayed significance, meaning the important corridors measured 6,000 miles of friction, and this is a comparison of the friction and macrotexture values for -- again, this is as for the mixes he had in the states what we call dense-graded asphalt concrete, typical Superpave mixes; although, we use a little bit richer mix than the original Superpave, richer in terms of little bit more binder.

And then there's SMAs available, and we see there in the left, the friction, and you look at the distribution, the SMAs have a little bit lower friction. This is not consistent, and you see the overlap between with the two distributions, some SMAs that have higher friction than some regular mixes and vice versa.

On the right they have higher macrotexture so when you balance the two -- the two properties, very equivalent in a way lower friction, the macrotexture that is for the high speed, we use those in freeways, in interstate system mostly, not all industry but most of them use (indiscernible) premium mix in a way, high performance mix, to reduce the cycle of -- and replacement.

So you see the little bit higher friction, lower friction, but a little bit higher friction than typical mixes.

Q. Higher macrotexture?
A. Sorry, higher macrotexture. I'm sorry, yes.
Q. Just to be clear, on the left hand chart, this is a sideways friction measurement via the script measured for the friction measurement; not grip tester, not locked-wheel tester.
A. Right.
Q. And then I just want to --
MR. LEWIS: Commissioner, I am actually going to be finished with my questions by our lunch break, somewhat to my surprise, but I'm very pleased with the way the technology is functioning and so -- which is great.
JUSTICE WILTON-SIEGEL: I was going to suggest maybe we might -- before you finish, it might be useful if we had a break now for two reasons. First of all, to determine how much time each of the other parties -- the participants will require but also to have a short discussion internally about one or two other questions which I have.
MR. LEWIS: So what I would

suggest is I would deal briefly with the early age SMA low friction issue and then just adjourn it then for those purposes.

JUSTICE WILTON-SIEGEL: Sure.

BY MR. LEWIS:

Q. So at image 38, there's a couple of paragraphs there, between the figure 13 photographs and the graphs above, about a potential concern with SMA surfaces a low friction when the surface is new. And if you can just describe -- we will be hearing from MTO witnesses about the experience, and Ontario, but if you can just describe that briefly?

A. Sure. One of the characteristics of SMA, as I mentioned before, is very thick asphalt binder covering the aggregate when -- so don't has durability in terms of cracking. So when you build this of course you mix the aggregate and the binder in a plant so the aggregate is all covered with binder when you place it on the road, so typically that happens with every mix. You have a very black pavement, slippery, more slippery than would be in a few months when the -- place it. So over time, the tracks and the cars peel off that binder from the aggregate and then you have the aggregate exposed, exposed microtexture, and then the friction -- reaches the peek and then the area that the polish is to go on again.

When you have SMA you have thicker binder so it takes a little bit longer for that binder to peel off from the aggregate, so some agencies are concerned about that so they -- in some cases, they do apply something is called gritting.

Q. Gritting?

A. Yes.

Q. Go ahead.

A. And what it is is as soon as you place the material when you're rolling it, you apply sand along the surface so you create exposed microtexture because of the sand that you apply, and then you compact that sand into the pavement and that provides higher initial friction and macrotexture. So it's kind of a short term treatment to correct for the early low friction issue.

Q. And then there's just a couple of photographs on there. If I understand you correctly, this gritting is done at the time of the initial application of the placement of the SMA; is that right?

A. Yes, during construction. After you place it when you start compacting, you place the sand and then you do your compaction on the sand. So the sand get imbedded in the mix and just expose part of the stone.

MR. LEWIS: I think that would be then a good time for break, Commissioner.

So in a moment, Registrar, I will ask this time that everyone go to their breakout room instead of being forced into separate rooms.

We're a little bit early for lunch but we're moving along well so I guess the first question, Commissioner, is normally we're 1:00 to 2:15, when you would like to resume and --

JUSTICE WILTON-SIEGEL: Let's keep to our 15 minutes, so 10 past 2:00.

MR. LEWIS: If counsel for the participants could confer and consider if they have questions and how they would like to divide their time and then we can have a discussion about that perhaps when we come back.

JUSTICE WILTON-SIEGEL: Okay.

MR. LEWIS: Thank you.
--- Recess taken at 12:54 p.m.
--- Upon resuming at 2:10 p.m.
MR. LEWIS: May I proceed, Commissioner?
JUSTICE WILTON-SIEGEL: Yes, please do.
BY MR. LEWIS:
Q. Just a final short series of questions before we turn it over to participants' counsel, Dr. Flintsch. It's not in your expert report, but given your expertise and you're here, hoping you can assist us.
Are you familiar with perpetual pavements, also known as permanent pavements?
A. Yes.
Q. And you can just briefly describe what they are, what the concept is?
A. The concept of perpetual pavement is an idea that is within the family of longer life pavements that the interstate has been moving to because takes some light traffic control and effort to rehabilitate the road that we're trying to design for longer periods that we used

20, 30 years ago. So now we design pavements that can stay in place for a long time with just minimum renewal of the surface.

The key design consideration within a perpetual pavement is to reduce the traditional what we call bottom up cracking, that initiate at the bottom of the pavement because of the continued flexion of the pavement because of the cracks. So what we do is we put a very high quality fatigue-resistant layer, similar to SMA again, with a high asphalt content -- sometime is the same design, sometime is different -- at the bottom of the asphalt and then potential structure of the pavement to accommodate and kind of eliminate, at least for a period of 40, 50 years, the need to rehabilitate and contract the pavement.

Q. So to overall -- extend the life of the overall pavement before a complete reconstruction has to take place?

A. Correct.

Q. Like with any other pavement structure there is a surface course in a permanent pavement structure and is it also expected that the surface course will -- I know it still has to be milled from time to time -- but is it expected that the surface course will also last longer or is that -- in a permanent pavement structure than a traditional pavement structure?

A. Yeah, that's not -- it depends on the structure, I would say. Of course, when you build a stronger pavement you expect the whole pavement to last longer because the stresses and strains will be -- they would be lower throughout the pavement. But also there's some other type of distress and aging of the materials and so on that not necessarily relate with the structural performance of the pavement but more with the functional performance.

I would say that you probably will get a little bit of -- but it's not the main purpose of designing a perpetual pavement. When we design perpetual pavements, we design knowing we periodically have to replace the surface layer.

MR. LEWIS: Thank you very much. I do not have any other further questions. Subject to any questions the commissioner has --

JUSTICE WILTON-SIEGEL: I don't have any, thank you.

MR. LEWIS: We can turn it

over to participants' counsel who have discussed time allocations and -- who is going first? Ms. Roberts?

MS. JENENE ROBERTS: Yes, so City of Hamilton council starting off, and we shouldn't be taking more than about 15 minutes of your time.

EXAMINATION BY MS. JENENE ROBERTS:

Q. Good afternoon, Dr. Flintsch.

A. Good afternoon.

Q. I just have, first of all, a few questions to ask you about some of the different countries that you spoke of today as well as in your report.

I know you've addressed friction management in the U.S., the UK, Australia, New Zealand and I believe you also mentioned Germany. I just want to know when you're referring to the friction management programs in those countries, are you talking about standards that are set and applied on a national level?

A. Mostly. I know in some cases, like the UK, they also apply to some lower level of the government, although I'm not a hundred percent sure that's the case for all municipalities or not. Again, it has been changing because the ownership of the road has evolved and -- they centralize with the -- and then recently they kind of -- with all the roads together into this national highways because before it was highways England and highways Scotland, and they had different denominations, but I not a hundred percent sure they do apply to every jurisdiction below the national level.

Q. So when you speak about those other countries, am I right that you're not addressing friction management programs that are being mandated and operated by the individual municipalities?

A. That is correct.

Q. Okay. Thank you.

Moving specifically to Canada. And we saw in your report and you spoke earlier about your understanding of friction investigatory and intervention levels in Canada. I believe you told us that you weren't aware of any published provincial or national standards anywhere in Canada for the investigatory or intervention levels; is that correct?

A. That's correct.

Q. You didn't mention Canadian municipalities, but I take it that also means you're not aware of any published standards respecting highway friction, investigatory or intervention levels for municipalities in Canada as well?

A. That is correct.

Q. So what that means is in Canada, on whether a national or provincial or municipal level, you're not aware of any standard for what is considered an acceptable friction reading on roadways?

A. At least not a published one.

Q. At least not a published one. Thank you.

I want to take you now back to a document that commission counsel put to you before, and it's Exhibit 11. If I could get that called up, please. While we're waiting for that -- for the registrar to call that up -- this is the agreed summary of pavement friction practices in Canada document.

THE REGISTRAR: Do you mind giving me the doc ID for it?

BY MS. JENENE ROBERTS:

Q. RHV932. Thank you. Here we go. So this is the agreed summary of pavement friction practices in Canada.

And, Dr. Flintsch, if I heard you earlier correctly, I understand that this document reflects your understanding based on the literature and consultations that you've had with some colleagues with respect to pavement friction practices in Canada; is that correct?

A. That is correct, yes.

Q. So I just want to take you through some of the content that's found in the document, and I'm looking at page 1 right here. If I could call out on page 1, the second paragraph under the first heading. Yes, that one.

So if we look at the shorter paragraph there you see, Dr. Flintsch, it refers to, first of all, the Transportation Association of Canada and we might have to -- sorry, zoom back out just so you can see the footnote on that one, apologies.

And, Dr. Flintsch, is this --

does this accord with your understanding about TAC, in particular looking at the second sentence here where it says:

"The membership of TAC," as well as another organization mentioned there, "the Canadian Council for Motor Transport Administrators, includes all three levels of government, consulting engineers, industry and other practitioners in related fields."

A. Okay.

Q. I take it that you understand that statement to be accurate, that the two associations we're mentioning here, TAC and the CCMTA, includes three levels of government, consulting engineers, industry and other practitioners?

A. Well, I don't understand that, but really I don't know. I never look into the association itself.

Q. Okay. That's fine. I know you have a little bit of a limited familiarity, if I can put it that way, with respect to Canadian practice as opposed to your broader familiarity with the United States and some other jurisdictions. Okay.

JUSTICE WILTON-SIEGEL: You should bear in mind this is not Dr. Flintsch's document.

MS. JENENE ROBERTS: Correct, yes, but based on questions from commission counsel, our understanding is that he had consulted with some colleagues and he read the literature and the content of this document is in accordance with his understanding as well.

MR. LEWIS: If I may interject, Commissioner. Dr. Flintsch was clear that it was, generally speaking, consistent with his understanding that there were no published intervention and investigatory level standards. And as counsel is aware, this is an agreed upon document to fill in Ontario and Canadian experience, which Dr. Flintsch was not called to testify on specifically.

JUSTICE WILTON-SIEGEL: Right.

MS. ROBERTS: That's fine. I did want to ask him about a couple of other statements that are found on page 1 of the document.

THE WITNESS: Just to clarify on the previous statement, I truly look into the technical aspect of the document and I truly don't know enough to comment on who is responsible for good -- for various aspects within the Canadian structure in a way.

BY MS. JENENE ROBERTS:

Q. Okay. If we could just look at that second paragraph under heading No. 1 again. I just want to ask you specifically about the TAC report. The 1997 TAC report -- the TAC guide that's referenced there. You see the quote that says:

"The actual designation of surface friction standards, such as minimum skid numbers, was not commonly practiced by province, states or local agencies in Canada and the United States."

Does that accord with your understanding, Dr. Flintsch, of the situation as of 1997 in Canada and the United States?

A. It is. Again, doesn't mean those standard was -- is not commonly practiced, that's a key part of that.

Q. Okay. That's fine.

And then if we look at the next paragraph here, there's a cite to a CCMTA report from 2016 called "Canada's Road Safety Strategy, RSS2025, Towards Zero, the Safest Roads in the World." And there we see that it outlines a vision for improving road safety collaboratively throughout an inventory of over 200 road safety measures that focus on road users, road infrastructure, vehicles and other initiatives. I'm looking at the last sentence there, it says:

"However, pavement friction measurement and management are absent from the identified safety measures."

Is that your understanding as well, Dr. Flintsch?

A. Not familiar with that document in particular so....

MR. LEWIS: Commissioner, I feel I need to intervene. Again, Dr. Flintsch has said that he's not familiar with all of the details and it appears that counsel for the City is -- if she wants to read this into the record, which it is already in, we can do that. But I don't understand the purpose of putting the specifics of this agreed upon document agreed to by the City and the MTO and other participants to Dr. Flintsch. We can do it but....

MS. ROBERTS: Look, I know commission counsel took him to the document so I thought it would also be open to the participants to take him to a document as well. To the extent that he is familiar with it, we'll get his information. To the extent that he's not familiar with it, I still think there's value in asking about the specific statements that are included in there.

JUSTICE WILTON-SIEGEL: I'm going to let you continue, but appreciating that you should be asking whether he has any familiarity with the statements -- with the documents from which you are extracting these statements. I suppose if you're going beyond this, really going to be talking mainly about MTO practice, are you not?

MS. JENENE ROBERTS: That is what the next section of the document goes to, yes. I did have a couple of questions about his understanding about MTO practice as well.

JUSTICE WILTON-SIEGEL: But -- I'll allow you to ask the question, bearing in mind that my understanding is he has already indicated that he has no familiarity with the MTO practice, no specific familiarity with the MTO practice.

MS. JENENE ROBERTS: That's understood. Of course.

BY MS. JENENE ROBERTS:

Q. If we can look at the second heading that's on this page, call up the second and third paragraphs that would be helpful, please.

Dr. Flintsch, I just wanted to ask you, based on your consultations with your colleagues and the literature searches that you were reviewing, is it your understanding about MTO that they are responsible for construction of an upkeep of provincial road networks and associated civil infrastructure?

A. Yes.

Q. And then are you also aware that municipalities are responsible for the maintenance of municipal highways and bridges within their respective jurisdictions pursuant to the Municipal Act 2001?

A. I don't have any direct knowledge of that but I assume that's correct; it makes sense to me.

Q. And then I just want to ask you about the final paragraph here, and this is more relevant to friction management that we've been discussing today -- you've been discussing today. It's your understanding and you're aware that MTO does not have friction management policies that establish numerical friction management standards; is that correct?

A. What I understand is there's no publish investigatory levels that have been published. I know that there are some policies that -- but not specific investigatory levels that have been published.

Q. Are you aware that there are no friction level action limits for highways in Ontario?

A. Again, if that's understanding like I would say there investigatory levels then, yes, but, in general, it sounds correct.

Q. Thank you. And then I think we can take this document down now. We're finished with this. And the whole document. Thank you, Registrar.

So, Dr. Flintsch, am I right

that a friction standard would permit a municipality to determine what steps, if any, might need to be taken if a friction test doesn't meet a standard friction value.

A. Well, typically, what we have been doing, at least from an entry level type of analysis, is we set some values where we said there's a need for investigation to define the friction is agreed to value. I know friction value doesn't mean the agency has to repave or anything like that. It's an indication that we probably should be doing something and friction could be contributed for -- to higher collisions that we would expect in a similar road with higher friction, but doesn't necessarily say that friction is a problem. What we could say it should be investigated properly to see friction is contributed to more crashes than would be expected and, in that case, there should be some type of intervention. That's one of the reasons why we got rid of this intervention, because we don't feel that necessarily the case. Friction is low, it warrants further investigation.

Q. So in the absence of any friction standards being set then there is no direction as to whether or not an investigation should be made or afterwards any sort of intervention should occur; is that correct?

A. Well, there is guidance because you can tell friction could be slower or higher than the rest of the network, for example. You could still make decision even if you don't have a written policy and you could investigate if it needed.

Q. But you're not aware of any municipality in Canada that has any sort of written policy that requires the investigation or intervention based on a measured friction value?

A. I'm not aware. But, again, I don't have a lot of knowledge about what the municipalities in Canada do so.

Q. Thank you. On to a different topic.

You spoke earlier about curvature in roads and cornering and for the friction considerations that are part of that context. And, if I understood you correctly, it's your opinion that curvature is a factor in the amount of friction that is required when you have, I guess, braking around a curve in the road; is that right?

A. That is correct. It's curvature and superelevation, both of them play a role, and of course some equations of (indiscernible) 3 and I think somebody else will testify in that later in the proceedings.

Q. Am I right that speed is also a factor that affects the amount of friction that's required on a curve?

A. Correct.

Q. And then the greater the speed, the greater amount of friction is required; is that how the equation works?

A. Correct.

Q. Okay.

Moving on to something you spoke about towards at the end of your testimony earlier. We were talking about SMA and I wanted to take you actually back into your report. If we could get that called up onto the screen. I know it Exhibit 13. It's EXP189. Sorry about that. If we could go to image 37, please. Could I have first paragraph called out, Registrar, please?

Dr. Flintsch, in this paragraph of your report, and I'm looking at the second sentence, in particular, you refer to a NAPA 2002 report. And you wrote there:

"Other reported advantages include noise reduction, improved friction resistance and improved visibility."

Am I correct that that was sort of the understanding in the field in 2002 about expected advantages of SMA?

A. Correct.

Q. Okay. And if we can go to section 3.2, and perhaps just call up the entirety of that section because I have questions on all three paragraphs.

In the first paragraph I see you cite a 2018 report by Yin and West. I think commission counsel asked you a little about this this morning. But am I correct that that study showed an approximate 15 percent increase in surface friction compared to traditional dense-graded asphalt section?

A. Correct.

Q. If we can go to next paragraph, you're citing here a TPF 2016 report?

A. Hm-hmm.

Q. And this is some testing

done in Virginia, so I imagine you're intimately familiar with this. You agree there that that study showed that an SMA section had higher macrotexture than the most common HMA mixes designed using Superpave methodology and it had slightly lower but similar friction, correct?

A. Correct.

Q. And in the last study that you cited on this page is a study in Japan and you agree that study showed a high performance SMA had improved frictional properties compared with a traditional dense-graded asphalt mix, correct?

A. Correct.

Q. And that's a 2018 study?

A. Hm-hmm.

Q. Commission counsel asked you earlier the question was whether the evidence is a bit equivocal about whether SMA gives improved frictional properties, and I believe you agreed with that question but just some clarification.

Am I right that the equivalence comes from the source of the aggregate so that essentially you have to look at the rocks that are in the mix and that affects whether the frictional qualities are improved or not?

A. Well, it depends on many factors, but I said probably, yes, the quality of the area has a big role of that. As we mentioned before, especially the resistance to polishing is very important in both SMAs and regular mixes. If you look at the report I also show a more recent study that some SMAs have a little bit lower friction and higher macrotexture, so frictional properties include both frictional and macrotexture, that's key part of providing good friction at all speed.

Q. So if you have a source of aggregate that gives acceptable -- that's acceptable, does that mean SMA is expected to have improved frictional characteristics?

A. Again, there are other factors play a role so it depends. And, again, in general, I would say a good number of the study that you have there show enhanced performance. Few other show it's not as good and, again, I -- depends on the type of mix, if it's SMA or dense-graded, it depends on the whole spectrum of materials that you use to produce a mix. That was my point.

Q. Okay.

A. You can produce SMA with very good frictional properties and you can produce dense-graded mixes with a very good frictional properties.

Q. I think you said there's a good number of studies that show that there is an enhanced performance with SMA?

A. Correct.

Q. Those are all my questions. Thank you, Dr. Flintsch.

A. Thank you.

JUSTICE WILTON-SIEGEL: Mr. Lewis, who is the next participant? We've lost Mr. Lewis.

MR. LEWIS: Next participants' counsel is Ms. Roberts, counsel for Golder.

EXAMINATION BY MS. JENNIFER ROBERTS:

Q. Dr. Flintsch, Commissioner, I'm counsel for Golder, Jennifer Roberts, and just to be confusing, we have two J. Roberts.

I want to stick with my questions from your report and allude at times to the asphalt guide which you also reference.

I want to take you back to the beginning of your report and talk about some generalities.

Registrar, would it be possible to pull up, please, a report which I believe to be Exhibit 13 and I want to say page 5. I think it's image 5, I'll call it.

Dr. Flintsch, you gave evidence earlier about the importance of friction as a component in road safety and you've alluded through the day to other factors and you talked a bit about speed, but I just want to go to some features that you've referenced that I think warrant some more detailed explanation.

In considering other factors, which are influential and frictional performance, would you include such features as horizontal alignment?

A. Yes.

Q. And that would be the tangents and curves on a road and, particularly the curves I take it?

A. Correct.

Q. So the higher frictional

demand the tighter the radius of the curve and the complexity of the curve; that's accurate?

A. That's correct.

Q. And the same with a vertical alignment, that is the up and down of the road. The gradient changes in road. That's also an important factor in frictional performance?

A. Yes, especially the downhill part of it.

Q. We've got reference, and I note AASHTO, and you allude to it -- it alludes to frictional performance affected by traffic volume, composition. I take that's trucks and just mixed traffic?

A. Yes, correct.

Q. And highway features, the environmental, and by that -- I understand that to be how complicated the entrance and exits to ramps and lanes are?

A. Correct.

Q. So all of that --

A. All the signs and pave markings, all type of features, all of those were affected too.

Q. So, in general, as the

highway environment becomes more complicated and difficult, the higher levels of friction are required to help drivers perform necessary maneuvers?

A. That's correct, because you have more uncertainty and more interaction between vehicles. All of that kind of increase the chance you will have to maneuver, and that's when you need friction and that could be turn or brake.

Q. Thank you. We talked, and my friend just took you to the importance of friction again. I don't want the belabour it but I do want to try and simplify it. Can I say this simply -- and you can tell me whether it's accurate or not -- the faster the drive, the less friction the road provides for you?

A. Well, the road provides always the same friction but the interaction between the vehicle and the friction in the pavement result in a lower friction is when you are going faster.

Q. And so just to go back to technical language, that's because there's decreased available friction on your tires?

A. Yes, correct.

Q. Commission counsel took you through, earlier this morning, to pavement friction management. I just want to circle back to that point because -- and you went through sort of the interaction between consideration of a assessment of friction, assessment of accidents. And if I bring in the issues that we just talked about alignment issues, traffic, highway features, do I take it that comprehensive and collaborative assessment of pavement management requires an evaluation of all of those factors?

A. That is correct. Typically, we -- as I was saying before -- use friction as a (indiscernible) and then when the friction is low we typically three years type of investigation, can see on those factors that you mentioned. In addition to others, too.

Q. And by others, you would include what else?

A. Again, the type of signage -- signage that you have, the quality of the pavement markings and things like that.

Q. So quality of pavement markings, that's like how clear the lanes are, demarcation of the lanes?

A. Correct.

Q. Whether you can see them at night?

A. You can see when it's raining and so on.

Q. Just to change the language a little bit, am I right in translating it that a safety evaluation of a highway to be comprehensive and collaborative would include an evaluation of the accidents, the friction values on the road, as well as the geometry and the other issues that you've identified -- the other factors, I should say more accurately?

A. Correct.

Q. Thank you. Can you please turn up page 15, image 4, page 15. I will get it right at some point.

So I just want to go to another topic, and this is, again, talked at some length about it. This is designing pavement for good frictional characteristics and you started with the point that choosing the aggregate is the predominant factor that determines frictional performance for asphalt surfaces.

And then you took us through a number of tests that are used that are indicative -- or used in order to try and establish an anticipated good quality and those are Micro-Deval, LA abrasion, and you also talked about the polish stone value test. I won't go into detail.

Am I to understand correctly that the AASHTO in fact publishes what are good property ranges for good friction performance or typical property ranges for good frictional performance for these tests?

A. I don't think we have a specific standard to say that, but the AASHTO guide mentions some typical good values for those, I believe.

Q. And this may be too much of an imposition on your memory, but your polished stone value, if I were to suggest to you that AASHTO said it was polished stone value, a typical property range for good friction performance was between 30 and 35, does that accord with your recollection?

A. I don't remember by memory. I'm sorry.

Q. That's fine. It was a little bit much for the memory test, I apologize.

I just want to ask another question. You talked about PSV. Are you familiar with a test called the polishing by projection test?

A. No, I'm not.

Q. CPP test, I think is the abbreviation.

A. No, I'm not. I'm sorry.

Q. I want to go to -- just briefly another topic that is measuring friction. I think it's probably easiest to go to your PowerPoint table 2, the examples of friction investigatory levels.

Registrar, is it possible to turn that up, please?

THE REGISTRAR: You don't have the image number for that in the PowerPoint. Do you, perhaps?

MS. JENNIFER ROBERTS: I don't. Maybe 12? Yes, that's it.

BY MS. JENNIFER ROBERTS:

Q. Okay. So again, I just want to cover off some simple points. And that is you provided evidence earlier today that you would expect that a friction -- that the friction number is influenced -- well, determined, in part, by the speed at which the test is taken. So the instance on table 2, the test is done at 50 kilometres per hour.

A. Yes, in both cases.

Q. And then --

A. Again, if -- 50 kilometres per hour et cetera.

Q. This is an investigatory level that is published for tests that are taken at 50 kilometres per hour. It may be obvious, but can you tell me what happens if you -- what values you would expect? Would you be able to provide an equivalency if that test were run at, say, 90 kilometres per hour?

A. The problem with that is you would need a macrotexture of the pavement to make that conversion. That even definitely be a lower value.

Q. And I can see from AASHTO they do run some conversion numbers for tests run at different speeds.

A. Correct.

Q. So you would expect -- so just as an example then, the motorway which has an investigatory level of -- for grip number 41, you would expect that number to be lower if the tests were run at a 90 kilometres per hour?

A. Correct.

Q. Last question. Thank you for your patience. In your report you identify a number of other techniques that are used to improve friction.

A. Hm-hmm.

Q. If I can ask you -- ask the registrar to turn up image 31.

A. In the other report.

Q. Sorry. Thank you, sir.

JUSTICE WILTON-SIEGEL: Before we do this, Ms. Roberts, I want to confirm my understanding. So are you saying, Dr. Flintsch, that the investigatory level for a motorway would be lower?

MS. JENNIFER ROBERTS: Let's turn that up again, please, Registrar. Turn the PowerPoint image 12. It warrants some scrutiny, Commissioner, because you will see that these tests are run at different speeds and you see numbers.

JUSTICE WILTON-SIEGEL: No, I understand that.

THE WITNESS: Yes. What happened is if you measure at the higher speed you're measuring a lower value, so the equivalent value of 30 kilometres per hour will be higher, so your number will be a little bit lower if --

JUSTICE WILTON-SIEGEL: Investigatory level will be lower because your -- definition measuring less friction?

THE WITNESS: Yes.

JUSTICE WILTON-SIEGEL: That's fine. I just wanted to confirm that. Thank you.

MS. JENNIFER ROBERTS: Thank you, Commissioner. You brought clarity to the point that I was apparently labouring with.

BY MS. JENNIFER ROBERTS:

Q. If we can please turn up 31. Thank you, Registrar.

Again, I just wanted to address one point, and it's a small point, in that one of the techniques you identify here is chip seals as being a possible option. Do you have an opinion as to whether this remedial technique is available in cold climates where we have temperature swings of more than 20 degrees Celsius?

A. I don't have any direct knowledge of that but I -- I don't see any problem to using -- in some places, there is problems with chips break windshields and some agencies don't like it because of that. But in terms of providing good friction, I say it could be a good -- as long as it's contracted properly. It's very sensitive to construction quality.

MS. JENNIFER ROBERTS: Thank you. Those are my questions and thank you, sir, for your patience.

THE WITNESS: No problem.

MR. LEWIS: Commissioner, I believe Ms. McIvor for the MTO may have some questions.

EXAMINATION BY MS. MCIVOR:

Q. Hello, Dr. Flintsch. I'll be very brief. My name is Heather McIvor and as Mr. Lewis mentioned, I'm counsel for MTO.

Dr. Flintsch, you referred to pavement friction management in the United States at section 2.5 of your report and in that section, I believe it was page 29, you reference the AASHTO Guide for Pavement Friction. I don't think we need to turn it up, but you'll recall that in setting out or referring to the AASHTO guide, you note that it describes three methods that agencies may want to use to set investigatory thresholds based on friction numbers. That's correct?

A. That's correct.

Q. I just want to confirm my understanding of that. So in model 1, the threshold friction number is marked to where there is a significant change to the rate of friction deterioration, or where that is expected as compared to pavement age; is that correct?

A. That is correct.

Q. Then in model 2, the threshold is marked to where a significant change to the rate of friction deterioration is expected as compared to crash rates; is that correct?

A. That is correct.

Q. And then finally, model 3, the threshold friction number applied is that at which there is a significant increase in the wet to dry crash rate. Do I have that right?

A. Correct.

Q. So am I correct to say that these friction related investigations, at least as recommended by AASHTO, are warranted really in circumstances where there are these marked significant type changes that are expected?

A. Yes, and also I want to mention that we have proposed a change to this method and based on crash analysis but, again, that current practice as it is. The new guide is not published yet so....

Q. Obviously, you would agree that these decisions all involve some balancing of prioritizing resources and setting investigatory levels based on what would be most pressing; is that fair?

A. That is correct, and that's why we propose to instead of doing it that way, doing through a benefit cost analysis that provides how much benefit you can get, not necessarily the places with low friction are the one that requires higher priority because they may not have the highest crash rates where you can get the most impact on the network.

Q. And so when you make that comment and you're talking about the shift, am I correct in my thinking then that this would be a shift further away from one standard friction number across all roadways that would be relied upon to trigger an investigation?

A. Yes, but even the -- actual pavement friction guide that's not talk about one number. What they talk is one number for each demand category that imply different type of roadways and different geometry, in general. You need high friction, as we said, in curves and downhills and things like that. So even AASHTO said you have to do these, but for each demand category is not one number for the whole network.

Q. I understand --

A. -- big change with respect to the previous approach we use for many years.

Q. That's very helpful, and I didn't mean to oversimplify things. I certainly appreciate your comments about all of the various factors that go into setting these types of thresholds. Those are all my questions for you, Dr. Flintsch.

MS. JENNIFER ROBERTS: And I'll just -- Commissioner, if I may, I'll just remind you that MTO witnesses will be speaking to the various provincial efforts in terms of the friction management processes that are in place in the province and applied to the provincial road highway, and they will be doing so in the coming weeks.

JUSTICE WILTON-SIEGEL: Thank you very much.

MR. LEWIS: I believe that counsel for Dufferin has no questions.

MS. MCALEER: I can confirm that's true, Mr. Lewis. Thank you.

No questions for this witness, Mr. Commissioner.

MR. LEWIS: Although Ms. McIvor spared us going to the page in the report, Commissioner, I'll give you the page and image number she was referring to about the AASHTO guide and the three methods referred to. That's page and image 29 of Dr. Flintsch's report.

JUSTICE WILTON-SIEGEL: Thank you. Does that conclude the evidence for today? I guess it does.

MR. LEWIS: It does, Commissioner. We finished -- we'll be refining our estimates over time, I hope, once we're particularly comfortable with the technology, but it seems to have gone rather smoothly today, so we'll start with Mr. Brownlee at 9:30 tomorrow.

JUSTICE WILTON-SIEGEL: Then let me just close by thanking Dr. Flintsch for his participation today and we'll stand adjourned until 9:30 tomorrow morning.

THE WITNESS: Thank you.

--- Whereupon at 3:01 p.m. the proceedings were adjourned to Wednesday, April 27, 2022 at 9:30 a.m.