NVF 34 and NordFoU
Pavement Design Systems and Pavement Performance Models

Session 8–1 Discussion on Performance Prediction Models

Byron: Well without further delay I think we will move ahead for the afternoon session. I'm Byron Ruth. I have the privilege of chairing the discussion session and I must admit that it's always a pleasure to come back to Iceland. And of course when you have nicer weather you can enjoy it a little more, but last evening at least I didn't get blown into the next lake or whatever, I was able to get on the bus without too much trouble and since we have this up here I'll make one comment. Years ago in a bearing capacity meeting we had a little tour, went through here, and we were in a Volkswagen bus with the wheels moved up and the overhanging... if you go around sharp curves and the people that were sitting in the back were hanging over the drop-off which probably left them with a queasy feeling.

But this was before they improved it. In meeting some vehicles going up, our driver actually pulled up along the rock cut and I thought he was going to take off his side view mirror. People could hardly get by and it was an interesting experience to finally get up on top and get to where we could actually drive through a little easier. But you could hardly get a bus or a Volkswagen Beetle to pass.

Well without going into further ado, what I'm going to do basically is go through some comments and we are going to come back to our panel and let them just do whatever they want to. But in order to make this successful I want people in the audience to actually interact, and that means if you have encountered a problem in the past which is applicable to our topics, if you are interested in something specifically make sure you speak up and let us know what your thoughts are. What I will do eventually here is go through and ask some questions, now I want to just leave this up here and you can look at it but before we get into those questions I want to make a brief presentation which may confuse you more than I'm already confused but I would basically just like to talk a little bit about performance models and the things that we have done from the standpoint of observation of performance.

It is essential that pavement performance models define the long term behaviour of all critical and necessary elements of in-situ materials and conditions. A lack of information regarding the pavement foundation, sub grade and moisture conditions may negate the best of performance models. Proper characterization of constructed pavements should provide reasonable estimates of predicted future performance. However the vagaries of nature may have a significant effect on these predictions. Therefore to be on the safe side, historic trends in temperature, rate of cooling, traffic, and so on should be used in the development of pavement performance models. Asphalt ageing and identification of conditions to produce cracking, rutting and deterioration may probably propose the most difficult task in our modelling efforts. In particular asphalt ageing which is very difficult to predict. There is considerable difference between the universally applied, applicable performance prediction models and one developed for regional use, where performance is dependent on fewer variables. And this brings up a point that used to be in States, every state said "well we don't do it that way, we do a different way" and I think that a... I am not implying that, but I am implying that we have simplicity, in some cases it works out. In some situations the effect of traffic and by tuning properties may suffice to predict pavement cracking. For example; the number of transverse cracks within 3 km of pavement where defined by the penetration of the bitumen for specific levels of traffic using data from numerous 7-8 years old test roads in Quebec.

High deflection pavements as characterised by dynaflex test produced no cracking when the recovered pen values where 98. So after 7-8 years if the bitumen had not hardened too much you could have very high deflections and no cracking even though there is traffic and of course you had all this thermal effect and thermal cracking in other sections. This indicates that the degree of short and long term hardening as well as the initial consistency of the binder has a significant effect on performance and performance models. Pavement research in Northern Alberta Canada suggests that the international roughness index can enhance our understanding of the effect of seasonal climatic variations on pavement performance and models. High speed laser profiling on the shoulder, inner wheel path and the outer wheel path was conducted on various highways for 6 years during the summer and winter. Winter freezing produced 15 to 25% increase in mean IRI over the measures that were taken during the summer. Proportion of kilometres designated as being good decreased in the winter. They had a level of IRI that they said this is where it performs well, is good, and when it got to high that was bad. The effect of rehabilitation indicated that IRI was substantially reduced from values obtained prior to rehabilitation but had minimal change for the summer time. So they could improve the winter time conditions but in the summer it really wasn't to much difference at all. IRI may not always be adequate or inadequate appraisal for pavement performance. Pavement with extensive cracking may give long surface lives provided surface and sub-surface drainage is very good. This really applies more to Florida, but on the other hand you can, as long as you have extremely good drainage, even in colder climates get by.

Now up here I am not sure that that will ever work with rain all the time and if you have any freezing you would have maybe severe deterioration. Anyways, to days presentation clearly illustrates differences as well as some commonality in pavement performance modelling. If it is agreeable with you I would like to conduct our discussions according to specific topics. And what we will do and I don't want to labour this at all, we will start with the first question here:

Need for performance predictions. Why are models of value for design rehabilitation, life cycle analysis, etc?

Now it might be obvious to you but on the other hand for some people it isn't obvious. So I would like to ask the panel if they would like to address that or if anyone in the audience would like to address that question. Don't think to long.

I think I can answer that I have this picture on my presentations. If you shall calculate life cycle cost and I think it is necessary to calculate life cycle cost instead of just investment cost, then you have to predict also the future function, the future performance, otherwise it is not possible and also if you shall go... and we are more and more buying function then most functional contracts. If you shall work with that we will have more than 10% extra cost for the contractors, because they have to take risk money and they will put risk money on top of their fee when they are doing this contract for us. So they have to be able to calculate the future performance, otherwise we will pay 10-20% more for all contracts.

Anyone else in the panel?

Gregers: Well I've been told by my director at home that it is important because we have a road which is going tendered as a, I think it is called built-operate and transfer project. So he want's to know what will be the development of the pavement condition over these 30 or 40 years and what sort of condition will he receive back after 40 year?. So he has asked for research into that.

Byron: Very good,

Leif? Use the mic if you could, they are recording this.

Leif: Do you hear me, ok. It´s also important to have these models to use for explaining for directors and politicians how to spend the money. They want better tools to predict concerning asset management. Deciding when to use money, how much money shall be spent in the future, and when to use this money. We have to have tools to document for other people that we are spending money in a good way. And also when these expenditures are coming,

and also what solution is best to use, for instance is it best just to use overlay or shall we better the drainage or other things.

Byron: That is really a key point, because you have to deal with legislators and so on in order to get money for projects over the long haul. So that might actually by one of the most important points of the whole thing. Any other comments? Andy?

Andrew: Is it on? I think it is really important that performance models are developed and I think for a whole range of reasons. In my mind performance models feed into the design process, and if you think about how roads are looked after, certainly in the UK, a lot of roads are looked after by local authorities. Local authorities don't have much money, they have lots of other pressures, schools, hospitals and the rest of it. So they have to spend their money very wisely and what that comes down to is being able to prioritize where the money should be spent. Behind all that, behind all the pavement management systems is that they are used to work out which road they should spend their money on. Behind all those, they should all really be underpinned by proper pavement performance prediction models. So at one level you might say why is it worth spending all this time fiddling with around with such complicated things because there are so many other variables that perhaps they might not be important in the longer term. But unless you do that it is very difficult to work out what is really important and what is not important. So I think in my mind that the case for developing performance predictions models is really critical. And I am just interested to hear what the panel thought about that really.

Byron: Ok..

Carl Monismith: Another facade of performance models is relative to something I animated yesterday and the performance models allow you to begin to look at pay incentives or disincentives in a much more rational procedure for construction process. For example you can have a performance model for rutting that reflects the important variables of the asphalt content and possible aggregations and degree of compaction and you can begin to define then, and if you have a target value for production and some standard deviation, you actually can define then what the pay-factor should be, should you deviate from the target value and have a larger or a smaller standard deviation. So this now allows you to develop a set of pay incentives not by actually saying that now I'm going to apply 40% to asphalt content, 20% to aggregating and 10% to this and X% for that but for a given project you can actually define the effects that have to be done. And what it does it tells the person that is doing the construction if I maintain the target values for design, and I have a small standard deviation I am going to get a very very good product. Secondly when you look at rutting, the most important thing is asphalt content, the next thing is degree of compaction, and the aggregating as long as you don't deviate too much has a relatively smaller effect. In the case of fatigue on the other hand if you look at the factors at least based for dense graded mixes that we deal with, the most important factor is the degree of compaction. The second is pavement

thickness and the third is asphalt content. Aggregating doesn't have much of an effect. So if the contractor is going to get good performance, then you see this from the performance equation that is based on observations and mechanistic principles. And you can define the impact on performance and from that develop incentives or disincentives. So I think performance models are very very important for this whole matter of the construction process and this can be applied not only to the asphalt concrete, it can be applied to the aggregate base, it can be applied to the compaction of the sub grade soils in terms of the impacts of each these on the performance of the pavement.

Byron: Thank you Carl, anyone else?

Bruce Chadbourn: I think that life cycle cost models are especially important in terms of publicly funded roads, where now-a-days when tax dollar is especially scarce you need to be able to convince the public that an investment is a good idea, in terms of saving money down the line. Right now it is difficult to get sufficient funding for road construction.

Byron: Anyone else in the audience here? Ivar?

Ivar: Ivar Horli from the Norwegian University of Science and Technology. I think performance models are important also for other purposes. For instance when you are utilizing new materials, as recycled materials, then it is interesting to see what effect you have on the pavement life and performance. And also when utilizing products that are more or less rest products from crushing plants, for instance more secondary materials, that are beneficial to use. What is then the pavement life if you are using such materials, going a bit perhaps on the borderline of the requirements? So there are also aspects of these regarding looking at some sensitivity analyzes, regarding using untraditional materials. When you are coming into new materials you don't know, you don't have the experience. So in that case it is also very important to have some models that we can use as estimates and have the best guess or, prediction of what the future performance will be. Thank you.

Byron: From your comments I gather one of the benefits is if you switch to a new material now you can make a prediction rather than just guessing, my gossh!. Right? Other comments? Go ahead Bjorn.

Björn Birgisson: Yes based on our experience models are very very important for example, if we go to a full mechanistic model like the one I presented earlier today, one of the benefits is that now we can start quantifying the effects of variability in the material. That is directly linked to construction variability on the pavement design for a given level of reliability, for example 90% reliability. A high construction variability will lead to increased thickness or, if you want to maintain the thickness

decreased life and this is something we are quantifying currently. Similarly if we keep the variability of the pavement material fixed, the properties fixed, at a given design level our framework can actually start, we now can start to evaluate the effect of variability in loading, that's traffic. So, and again that translates into either, for a high traffic variability that can translate into higher thickness of pavement which means more cost, or decreased life. So immediately by going towards more mechanistic approaches we provide and incentive to contractors to do a better job, during the construction process. Be better at insuring uniformity during construction, which directly translates into freeing up money that can be used for other things. Thank you.

Byron: Per?

Per: Maybe I can give an example. Some years back probably 20 years ago I overheard a discussion at the Copenhagen airport. They were planning a new runway and two engineers were discussing whether they should use 500 mm of asphalt as they had been doing on the other runways or whether 400 mm wouldn't really be enough, because they had the impression that the sub grade was pretty good, it was sand, and probably 400 mm would quite sufficient. Now that was a 10 million dollar question. And they were just discussing that sort of on their gut feeling, eventually they said we probably better do the 500 mm as we usually do, then nobody can come after us. But if they had had some good performance models then they might have been able to make a better decision of that.

Byron: That's a good comment because my personal opinion in many cases we can use less asphalted concrete provided that we do a really good job on our granular base and make sure that we have good drainage and sub-grade support.

Lev: Similar to what Carl said, an understanding of performance will help us better control field work and better identify parameters which we are supposed to control, so instead of just controlling density of the granular base level also control the middle properties. When we started doing the concrete part of the mepgg, we believed that the flexible strength of concrete is the main parameter. Now after we finished the guide it is maybe the second or third in line, more important is thermal expansion and built occurrence how smooth the pavement is constructed. Today we have done some presentation for top down cracking where you just have to control all this spatial .. .constant. In this case many other parameters which you control now might be relevant. So just selecting what you have to control can help construction and design.

Byron: Thank you. Anyone in the audience would like to make some comments? Let me throw one other thing out. In the United States in more resent years we have warranty contracts, and these are generally 3-5 year warranties. And the contractors now are basically assuming responsibility for that pavement. If there is a maintenance problem or whatever. Now how are they able to do that without performance models? I'll tell you. It's based on there historic work with certain specified mixtures and they basically know that they are going to last for that period of time. Now if you extent that over a long period, to have a warranty for 20 years or so becomes much more questionable. And I think that's one other aspect of this business of performance predictions. Shall we move on to the next subject?

Should pavement rutting and cracking models be considered as separate and independent?

That maybe a loaded question but I put it up there on purpose to see what I could gleam of the panel and the audience.

Anders Huvstig: I think they should be separated and the reason for that is that I'm not a researcher. I work outside in the region and I think if you should use very complicated models that take a long time to run they will not be used. So today, with the computers of today and the programs of today I think it is only possible to use separate models and in other ways it would not be used for real road design.

Byron: Thank you. Anyone else on the panel wants to address this? Carl?

Carl Monismith: From an engineering standpoint I agree with the person but from a research standpoint I think it is at least the people that are looking at the developments of models ought to actually consider both the effects of permanent deformation and cracking together because they may interact with each other. But I think that the complicated factors that one will run into particularly if you start looking at finite deformation theory as doctor Weismann has been doing for us. It is not a kind of thing you would use in a design model but it might provide guidelines for the types of test that you might eventually use for improved performance, particularly for very heavy duty highways. So I don't see it as a design tool I see it as a way of really seeing the interaction between these effects that may help us do a better job in design eventually. But I do agree that from a current design standpoint we really have to look at them separately.

Byron: Anyone else? Did we kill the subject? I may make one comment on that. Indirectly if you look at pavement performance in the field and I have observed this in one particular case. You have block cracking because of aging but no traffic. You had shuffing, you had severe rutting and then of course there was a little bit of alligator cracking but most of this was due to the truck traffic pattern and the movement of trucks, more than it was just the cars and lighter vehicles. So my perception here, I would agree with what's been said but I would also say that if you have a mix that ruts rapidly it implies that it is not a quality mix. And that may have bearing on crack resistance. Of course that maybe goes back to asphalt content but if you don't have reasonable quality I don't see that the resistance of cracking is going to be much better. So you can take that with a grain of salt if you wish. So shall we move on to our next question?

Is it desirable to develop acomprehensive or interactive model that is applicable worldwide, or can less complicated, more regional, models be used effectively?

That maybe a loaded question but its a one that I thought might turn up a bit of discussion. Ohh go ahead.

Björn Birgisson: I'll attempt to address this in terms of a weep down. I believe that if we go fundamental enough on the modelling, where we work with fundamental concepts and fundamental properties, the model is right away going to be universally applicable. We may have to do some tweaking but for the most part it will be applicable. So it really answers the question I think.

Byron: Thank you.

Inge Hoff: I agree that if you could be fundamental enough it could be forward. But if it will be several models of course, a frost heave model could be universal, but might be not that interesting in Florida.

Byron: We are back to the regional concept. Anyone else? Andy?

Andrew: I think this is kind of linked to the previous question as well about this separation of rutting and cracking. In my mind at the material level, the material responds to certain states of stress and strain and it is those states of stress and strain that dictate what sort of damage evolves in the material and what you really want to do is come up with a sort of constitutive model that encompasses all sorts of different situations. Now that's quite difficult to do, there are number of groups around the world that are working on that and they are making very good progress but it is actually quite difficult to do. Which I think explains the willingness to separate the damage mechanisms out because they are perhaps easier to tackle on their own. So in the short term I think that tackling them separately is the right way to go, particularly for practical design purposes. But in the long term I think the goal should be to try and achieve a much more integrate constitutive model where it is really the states of stresses and strains that drive whatever damage accumulates. And I think it is the same answer really to this question, I agree with the comments that have been made so far. If you have a fundamentally based model it should be applicable anywhere. But I think in the short to medium term as has also been made I think that some countries will, for very good reasons, focus on particular aspects. You know frost heave is not an issue in the UK so we wouldn't spend a long time developing those sorts of models. If you had a fundamental model that did everything that would be fine because that would predict those sort of problems in the UK, but I think we are a fair way from that at the moment. So I think inevitably in the short term different countries, different regions, will focus on the distress mechanisms that are particularly relevant to them and particularly feed into their design process.

Byron: Thank you. Just one comment on that. That's the reason that I mentioned this Quebec test road because the prediction was extremely good and we had it in different traffic levels so this is actually lower to medium traffic. I forget what the R square was but 0,9 something. Anyway if you looked at it, it looked tremendously good. Then when you went to the heavy traffic, and this is with thicker pavements, it went from about 3-4 inch pavements, you go to heavy it was 5,5 and it is just like you transpose that curve up so you got more longitudinal cracking. Now why? Well you have heavier trucks associated with the thermal stress. So that was a simplistic approach, and I don't say that we should always be so simplistic but at least you would have something that would fit into your regional system. Any other comments or questions relating to this? Alright we go to the next one.

Need for future development, in performance models: What is most critical, what is needed to achieve reliable prediction, based upon your perception of prediction models that you have either been working with or from the standpoint of general types of prediction models that have been presented here today?

Bruce Chadbourn: I think accurate characterization of materials, as many materials as possible is really crucial as a starting point.

Byron: Thank you.

Inge Hoff. It would be easy for me to say we need more research, because that's what I do for a living, but actually what I think is a good approach is what Anders has started. Just soon as you get something started, use it. Then the need for research will come on its own. And I think that is really the only way to make this go forward. Because a lot of research and laboratory testing does not apply, does not get us anywhere.

Byron: Clarify that a little bit. You are talking about using it on preliminary operational basis to see how it really works and fits, which means that you are going to do this over a period of few years.

Inge Hoff: No actually, I guess Anders could explain this better by himself but actually use it in contracts, to let the contractors start to use this new models as we develop them.

Byron: That's what I meant by operational. That would be just like anything else. If you have a construction, a change in construction process, and you are not sure that it's the best you do it on a preliminary operational basis to evaluate it.

Anders: Yes I can say a little more about that. What I think is very necessary is to make prediction of future performance on real projects with help of consultants and of course contractors. And the reason for that, you do a lot of tests and I think that actual tests are the only way today to tell what rutting it will become for example. And if you have a lot of tests then we will see the variability. We are talking about variability but we will not see it before we make all these kinds of test, have a broad experience backwards. But I think the most important thing is that we'll have the big .... that is hidden today as a result of consultants, and especially contractors who are building roads, they are not interested in a good quality because we don't pay for it. But if we are calculating it we will have this experience backwards from them. And it's not just couple of researchers sitting here, it's hundreds thousands of people that will get the experience backwards. I think that is the most important thing, to have the knowledge going up in the working sites.

Byron: I think that is a key point. Lev?

Lev: I'm kind of in line with what has been said before.... I would like to suggest another approach. If you have developed a new model try to explain predictions in road sections, because it's a really.. I was doing an experiment which a lot of information was collected prior to construction and during construction. The researchers monitored almost on monthly basis. I don't think that anybody in the road... has as comprehensive database as my road has which is relevant to cold climates... And on the same note, the next year, the road will go

through the construction stage. So that's kind of implying what you say, if you have a, or like to predict performance it is better to predict not just for a road under construction, known traffic and known conditions but section which would be monitored for traffic, temperatures, moisture.. would be monitored for years. You can objectively.. experience. engineers and consistent ways. So that actually can be a really good point for, focal point for, calculations and changes for years because everybody will feel that similar data sets and information and if there is any major breakthrough will become available to everybody. And another side one of the main drawbacks of road database..... don't have enough resources to really analyse the data. The real outcome of the experiment would be much greater if... the research community will have to make sense of the data.

Byron: Thank you. Pierre did you have something?

Pierre: Yes looking at the French situation. I think that we would like to improve two things, the design of pavement re-enforcement. When you start with damaged pavement, cracked pavement how do you take into account in the modelling of the reinforcement. I think that is one of the weak points now in the French design method and we have also problems sometimes with premature failure of wearing courses, due for example to shearing or due to de-bounding between the wearing course and the underlying layers. And we also don't really understand and know the mechanisms of these de-bounding and we have no proper tests to characterise this de-bounding. So these are also important aspects and pavement rehabilitation is much more important in French than design of new pavements.

Byron: I am going to come back and ask you a question. When we talk about pavement and you are going to upgrade them, rehabilitate etc. And you have models. Now is it the models that are going to give you the answer, you have to start with information. Which means that you have to have a thorough evaluation to find out what is causing these problems? And if you have a pavement section which is supposedly constructed the same way, a part of it in a very good shape, a part of it is coming apart. You have a perfect comparison which makes it easier to assess what is going on. Now I am not saying the model couldn't help you but on the other hand one of the big problems is acquiring this information so that you can do the right kind of forensics. I don't know what you would like to comment on that. You have any comments relating to that.

Pierre: Sure it's the other part of the problem, is to have proper measurements, and actually we have now a project on that in France, research project, looking at deteriorated pavements. And looking at explaining better deterioration mechanisms and also finding better non-descriptive tests to identify this premature deterioration. For example de-bounding or things like that, well I'm more in the design of pavement and modelling aspects so I would say that we need better models. But we also need better methods to understand the mechanisms in situ.

Byron: But you use FWD?.

Pierre: FWD is not so popular in France, I think ee..

Byron: Do you have any non-destructive tests?

Pierre: Yes, some FWD tests are used, we also use deflectographs, like Benkelman :.....automatised test, we use also surface waves propagation test for some applications. Rather we have different methods of course, but I think that more could be done in this field. For example working only with the deflections, deflectograph, people are convinced that the deflection is not a very good indication of pavement deterioration, before you get really strong damage. But deflection is not a very good indicator of the beginning of damage.

Byron: Let me be true. If you have a pavement which is fairly severely cracked. We did this on one airport, taxi-road. It was cracked enough that you go out there with FWD and say boy all these cracks are going to affect it. But we ran it at a series of temperature and at high temperatures you negated the effect of the crack so we could then look at the sub-structure. And then we defined, basically, the margins of the asphalt concrete based upon laboratory tests that we'd used before including viscosity. So you know there are little tricks that sometimes you can play which may give you additional information. This is just one example. Bjorn? You are hiding back there.

Björn: Thank you Byron. Björn Birgisson. I think from our point of view there is only one truth and that is what is in the field. What's the pavement out there? And as such it is important to model the events that occur on the pavement very carefully, where we are missing a big piece is to clearly identify the sequence of loads and environmental events that lead to failure, and I think that goes back to having good forensics. Having a comprehensive program to monitor key pavements under different conditions out there. We need to understand what brings on failure. That allows us to make progress, in our world and not in science land.

Byron: Carl?

Carl Monismith: I think what is needed is for people not to wait for the perfect model but rather to use what we have and do things. I know sometimes it is difficult to take changes because you want to have the best answers. But it seems to me that we have enough experience now and agencies have models that are workable and I really feel that we ought to be using these more than we do and then observe the performance and gradually change the process as we get more information. So, if we wait for the perfect model, we will never get there, the problem is a difficult problem but we have a lot of good information and I think we can design better pavements with the information that we have today then we are doing. So I would encourage people to use these performance models that are available to them and the environment they are working in. And follow the performance and observe how you are doing, I think it is very important to do that.

Byron: I agree with you 100% and when I say a preliminary operational evaluation that can apply to anything, including the performance models, we should actually go and use them on regular projects. Well there are a little bit, Minroe,. well that's a little bit different but when we use test tracks AVS in situ for constructed sections like in the big fields or laboratory tests. Actually that does not tell the engineer what is the true problem out there, and we got thousands of kilometres of test road running all around. And some of those you can get on and

unfortunately in Florida, it is very difficult to get out on an interstate because they will run you down. If I lived there I would worry about that. But the point being that you have to use existing pavements to find out, from a forensic standpoint what is causing the distress or the problem. And if you get design engineers, material engineers, construction engineers or a representative and if they'd work as a small team and did some of this they would learn what is haywire in our state or region and how can we address those problems. At least that is the perception I have. Yes. Terhi

Terhi: Terhi Pellinen Helsinki University of Technology. Do you think it would be worthwhile if you would have some kind of international competitions, let's say if World Bank would finance some roads and they would have a competition to design it and in this way they would kind of like different models, maybe would compare them and have the good models out there and see how they actually would perform?

Byron: Bruce?

Bruce: I think that that could be really exiting, especially for university students.

Byron: Gunnar.

Gunnar: My name is Gunnar Bjarnason and I'm from the Icelandic Road Administration. I think I should mention one, I think our largest problem here in Reykjavík for asphalt concrete is rutting caused by studded tires. We haven't really done enough research in this area but we think that the permanent deformation in these asphalt concrete layers is about 10-25% of the whole rutting. But then the rest is rutting caused by studded tires. And I don't think that I have heard anyone mention anything in these models, taking studded tyres, the abrasion caused by studded tires taken into account.

Byron: That's a good point I have written some other notes down relating to that and my only comment at this time would be that if I was to address that problem I would go and look at the tyres and vehicles. And you already have vehicles out there with air on the run where they can go out in the hinterlands and reduce the tyre pressure and go up in the snow etc.

Anders: Well we had that problem in Sweden many years ago but I think we solved a lot of the problems, not all of the problems of course, with help of, I think some people here can explain better, but the studs today have much more plastic in them, but we improved pavement and we have tested the wear in the … research institute. Improved it by using splitmastick. lot of hard, big stones in the surface and we have hard stones also in the surface like porfyr. The problem today is that we have some kind of problem with slippery on this porfyr because it is to hard. But this is the way we solved it as I think it is about 1mm per year today this rutting from studded tyres. And it was much more. I think we had to resurface once a year or once every second year in Stockholm.

Byron: Thank you. Inge.

Inge: In Norway we also for many years believed that wear for studded tyres was the only problem. When we started to use lightweight studs and also decreased to amount of cars with studded tyres the focus is now maybe isn't that studded tyres that take it all and rutting might be a bigger problem than we earlier thought.

Byron: My understanding in the past, is that when you have damp pavements, and this is based on laboratory testing in Norway, I think. You have a lot more erosion of the surface due to studs then when you have a dry pavement, and that may actually be performance information to us. I'm not sure. Leif?

Leif: I can supplement what Inge said that 30-40 years ago studded tyres were perhaps the biggest problem in Norway. Then we used mixed design that was imported from outside Norway. This was solved gradually by introducing stronger materials, better stone quality and also bigger stones in the pavements and on the other hand it was working with less studs in the tyres, smaller studs and lighter studs and also now the last years we got friction tyres without studs. So nowadays this problem is reduced very much and we have only a, 1/3 perhaps of the wear we had 30 years ago.

Byron: Do you consider that you have made enough change there so studs don't pose a problem at the present time?

Leif: It still is a problem because there has been much increase in traffic and we still have areas up north that have to use studs, but it's much less then it was before.

Byron: Ok thank you. Any other comments on studs? Ivar go ahead.

Ivar: Ivar Horliv, I can also give some additional information to this regarding what we have been doing in Norway. Because we have now finished a four year project on that, with studded tyres. And what we did was to make test sections in four counties in Norway, from north, to the middle, to the south. So that we could look at this problem in several climate zones. And in addition we utilised the big facility or the round track at Videa in Sweden, so we tested several mixtures. Because still there are problems with studded tyres in Norway even if they are reduced. The problem is that the focus now is more on the friction and silent pavements and so on. So that we might run into the problem that we are going to new mixtures that are not so good regarding rutting resistance. Because the focus is not there, so much now, but it is only in the biggest towns that the rate of use of studded tyres are less. So it is a need to utilise the strong aggregate still and what was interesting in this project is that we could use the Swedish model. So the model is there, and it was now calibrated to our rock types, so we made a step forward on that knowledge about rutting. I think it should be integrated in deterioration models as we still have problems and it is a economical issue also. So the main thing is that our models can take care of all these mechanisms so that we don't forget any aspect of interest, if there is a certain amount of deterioration. So I think this is also important in other countries also. I know that in Alaska they are working a lot with this so they have integrated these models in their mix design at least. Thank you.

Byron: Thank you. Gunnar.

Gunnar: I think that maybe 10-20 years ago people here in Iceland decided to try to tackle this problem by lowering the air voids in the mix, even down to 0,4 and increase the bitumen content. This we think, might of course increase the permanent deformation, so we are trying to solve one problem and get another instead. So this is what we have been trying to do, and should try to do something else in my opinion.

Byron: I must admit there are many things when we try to solve one problem then create another one, that's not unusual. Well does anyone have another comment relating to this? Ok Andy.

Andrew: I've been interested for the panel's views on this. I think sometimes, some of these things relate to the type of contracts that operate in the pavement industry, and that relates to risk. In the UK the way it works is that the risk is either held by the highway agency, they procure a road, somebody designs it and builds it for them and then hands it back to the highway agency and there might be a guarantee on it for a short period. But ultimately the highway agency has the risk for that road. The alternative type of contract is one where there is more of a finance operate contract where a consortium might look after a road for 40 years, where the risk is not with the highways agency at all but it is with the consortium. In the first type of contract, if I go to the highway agency with a new design method based on some fancy performance prediction tool, then I'm going to have a really hard job of selling that to them unless there is a large amount of data underpinning it. Because the highways agency in the UK are very very risk adverse, because they are dealing with public money, and they are very risk adverse and they usually revert back to empirical designs. So that's kind of quite difficult to do, it requires a lot of time and data to back it up. And the same is true for the consortium, the consortium obviously don't want to take the risk either for the same reasons. So I just wondered what the panels´ views where on the ways risk should be dealt with. I'm not sure how it works in France, but I understand it is much more of a risk sharing procedure between perhaps the central government and the contractors. I don't know if Pierre has any particular comments on what happens in France. But I'd be just interested in the panels' views on how perhaps innovation could be encouraged by the type of contract. Because it seems to me that, that's ultimately where the risk lies that dictates whether somebody will do something or not.

Byron: Any comments, Pierre?

Pierre: Yes well one way to solve this problem in France was to have a kind of innovative projects in which in fact you have to… For example if you want to test an innovative technique you have to have an agreement between the company which wants try this product and the state which guarantees that the, which verifies the study and with the local authority or state authorities which accepts to make this innovative project. And there is process then to validate the behaviour of this material. The risk is shared between the company and between the owner of the road and then the state organization which supervises this is called CETRA it's not a CPC it is another organization of the road directorate. And the CETRA validates then, usually it's a field experiment, for example you build a road with the new product and you have to follow it for three years. You have to follow certain criteria in your study you have to make a laboratory study. If it is a new product you have to characterize the production and then you have to characterize the in-situ behaviour and after that a kind of certificate is given to this product. And then it is certified by the road authorities that the behaviour of this product is satisfactory and then you can use it on other projects. So there is a system like this in France. But I understand that the organization is changing a little bit, it will probably not be

anymore CETRA which will be responsible for following this project, but a kind of association of the different organizations, the main road works companies, the state and research organization like LCPC. But it is a way to introduce innovation in road projects.

Byron: Thank you Pierre. Does that answer your question to some extent.

Andrew: Yeah I think that the upshot of that is.., my impression is that the French have actually been much more innovative then we have been in the UK and whether that is a direct result of that arrangement I don't know, but it seems to me that risk sharing is one way of encouraging innovation and that doesn't happen very much in our system.

Pierre: Yeah I think in great part this process helped the innovative solutions it's true.

Byron: Bruce?

Bruce: Bruce Chadbourne Minnesota has many small contractors who are unable to take on a lot of risk. And as a result Minnesota tries to minimize risk with a system of incentives and penalties on paving quality.

Byron: Anders?

Anders: I think that the French is very good in that and I think we are not working very good in this way. The reason for that is that the rules for competition, the European rules for competition is a problem especially for people who are working with them. And I think that is the reason for that we don't buy contracts in this way. But we are starting out to try to buy functional contracts, and in many more years I think it could be a solution…

Byron: Carl?

Carl: A different approach, just for at least one project has been tried in California, the I710 freeway rehabilitation came up for possibilities and the industry had suggested that the solutions should be, an asphalt solution to this. So the CALTRANS formed a joint industry CALTRANS task group which the University became a part off. Now initially the CALTRANS people designed the freeway. They had a standard overlay design for the concrete partition that was away from the over crossings. They designed a pavement for the section that had to go under the over crossings. And the section could not have been built in the 55 hour closure. So the University was then asked to work with this joint industry and CALTRANS group and a pavement was designed, but to design that pavement required different testing then was required for the conventional procedures. So the industry put up some money to support that design. And then the results of the research were suggested to CALTRAN in terms of the construction so the construction documents were changed in terms of compaction. The idea of a rich bottom was inserted and industry and CALTRAN agreed to that. The use of the modified material as the surfacing on the course was agreed to and this working together then provided the incentive to go ahead. But at the same time then there was a concern that, would the modified material under these very heavy traffic conditions rut. And so industry actually provided the same material as was thought to be used in the freeway. They sent this to the field station here in Richmond and a mix made in the central plant was actually placed on top of the existing concrete slabs that we had there. The heavy vehicle simulator tests where done. So the cost of this was in fact split between CALTRANS and the industry to accomplish this particular objective. And when the results turned out it appeared

reasonable. Then the project went ahead and it was lead to bit and the specification requirements were quite different than the regular CALTRANS specifications. So in this way, a project which was different then might have been done in a way came about because of the fact that the constructability in 55 hour closures governed what could be done. This is just and example on how something was done in least one case. Now whether or not it is going to last for thirty years, I hope I die before that fails. Thank you.

Byron: Before I move on here I have just a quick comment and this goes back to use of studs. I came to the conclusion that you do not live in a suitable climate. It isn't cold enough and you don't have enough snow. Now there is reason for that. I used to live in Montana around Bozeman and I would drive down to towards west Yellowstone and they would have about four feet of snow and it was fairly cold. And when they ploughed out the highway they actually built in more super. So on dry pavement you could only drive 35-40 mph in many a location, after that you'd be whipping down there at 55 with snow tyres. But you didn't have to worry about studs. So you maybe better install some snow blowers.

Gunnar: If I could just add something to this. The reason during the winter that we don't have any ice on our roads here in Reykjavík is that we get rid of it by using de-icing salt and that is another question. I've been asking some people over the years what is the effect of salt on the stiffness of asphalt over many many years. And nobody has been answering this question.

Byron: Anyone wants to respond? Ivar go ahead. I don't have the answer but I have a student and he is working on this so he has started in co-operation with the Norwegian public roads administration and he is now doing tests, the tensile test also the sennen test and some other tests and is looking at the effect of salt and comparing with, if you are having the conditioning in salt or in pure water, or dry. So that will be very interesting, so we need more students.

Byron: Thank you. I like to ask Andrew to make a few comments. I think you were going to address there. I have been doing that,, ohh you are sneaky. I didn't pick up on that. At this point we have gone through quite a bit and I suppose everybody is getting tired. The last basic question I had was just to ask you if there where any other topics that you wanted to discuss. And I´m not sure at this stage of the game that there are, but if you do, just speak up. At least you are awake. Well thank you very much I appreciate all of your comments and effort that you went through in presenting in what I think is a fairly fruitful discussion and I am going to turn the meeting over to the chief. And before I do that I would like to have a big round of applause for Haraldur because he has done this whole operation by himself, essentially. He's done a super job and so (applause) congratulations.

Haraldur: Thank you this was maybe to much but. Before I give the word to Hreinn Haraldsson for the closing I have two comments. I would like to ask all the speakers from yesterday and today to meet us here after the closing and concerning the Saturday tour, that's tomorrow the bus are going to leave here at 9 o'clock. Just in case, sometimes it is raining here in Iceland so take good clothes with you. Then I will give the floor to Hreinn Haraldsson the director of the road research and development of the Icelandic Road Administration. Thank you.

Hreinn: Dear participants of the seminar. As Haraldur said my name is Hreinn Haraldsson and I'm director of development of the Icelandic Road Administration and I'm also the Icelandic secretary to the Nordic Road Association NVF, and also the Icelandic member of the board the Nord FOU are events that are similar to those we have been attending. And I

have the privilege to make the concluding remarks of the seminar for these two days. We have now behind us two days which have been filled with lot of interesting presentations and discussions. Interesting and informative days which in our opinion at the Icelandic Road Administration have actually more than lived up to the expectations we had, for the outcome of this event. As presented at the beginning the seminar is organized on behalf of NVF technical committee 34 on road structures and Nordic Road Co-operation platform Nord FOU. And both parties are now working on pavement design systems and pavement performance models and the seminar is intended to act as an input to their work. It is therefore extremely valuable to have had the possibility to incorporate the new ideas and development in other parts of the world. While we are in the middle of this important task we have. Not least from our distinguished guests from abroad and I mention first from the United States, but also from other countries, countries in Europe like UK and France. And on behalf of the whole Nordic community presented here at the seminar I bring forward our sincere thanks to your contribution. But also the inputs from our colleques in the Nordic countries give important tribute to the ongoing work and were hopefully also interesting for the representatives coming from other countries. Here in Iceland we have in front of us now numerous projects with new road construction, we have so much money in the next 12 years if we shall believe the politicians. Actually we have elections after two months so it might change after that. But we have a lot of new ideas, a lot of new projects, the heavy traffic is continuously increasing on our relatively weak road network so all new knowledge on pavement design and pavement performance is extremely important to us here in Iceland. We hope that the location for the seminar, here on an island in the middle of the Atlantic ocean shows a good example of an ideal meeting place between east and west as was the case 20 years ago, at the summit meeting of Reagan en Gorbachov. And despite the weather we experienced last night which I hope that you understand originated at the east coast of America, just happened to pass over us innocent Icelanders and continue towards northern Europe. And despite this we hope that the atmosphere here in the professional and social meetings only leaves positive memories from your visit to Iceland. Finally I like to congratulate the organiser for the excellent work and especially Haraldur Sigursteinsson and I was going to ask you to have a big applause but you already had that, but perhaps you should do that again. (applause) But also many thanks to all the speakers, to all the session leaders, to participants in the discussions and finally but not least to all the participants in this seminar. I declare the seminar closed. Thank you. (applause)