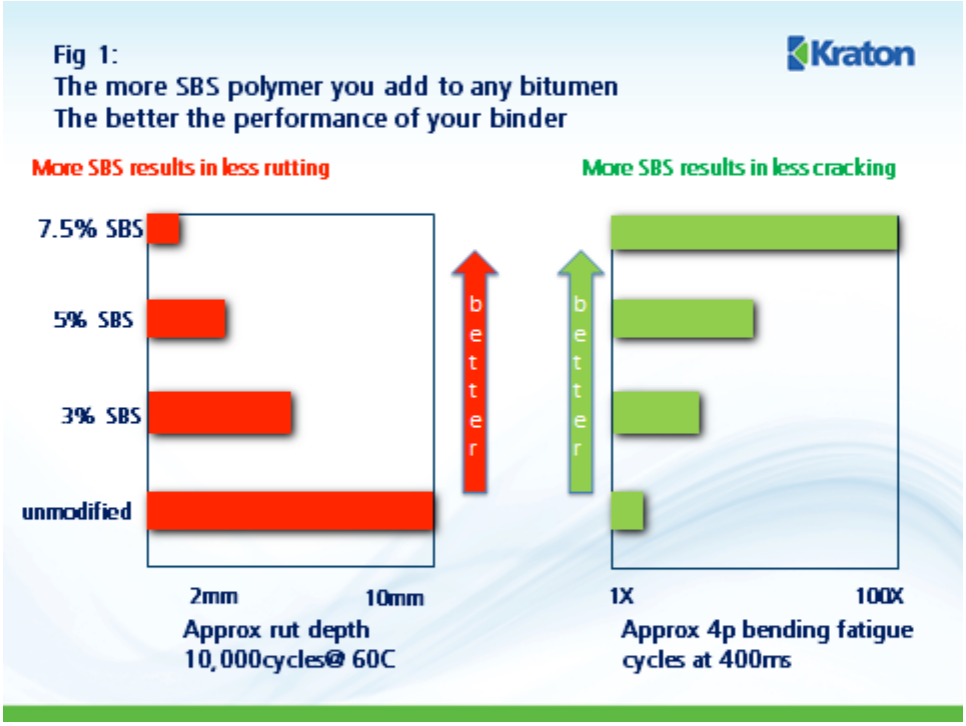
# How does one "deliver new age road pavement solutions"?

Presented by Vincent Conserva
Australia & New Zealand Business Manager for Kraton Polymers
He graduated from Adelaide University with a Bachelor in Chemical Engineering in 1980. Has worked for more than 30 years in the petrochemical industry and with Kraton Polymers since 2000. He resides in Melbourne.

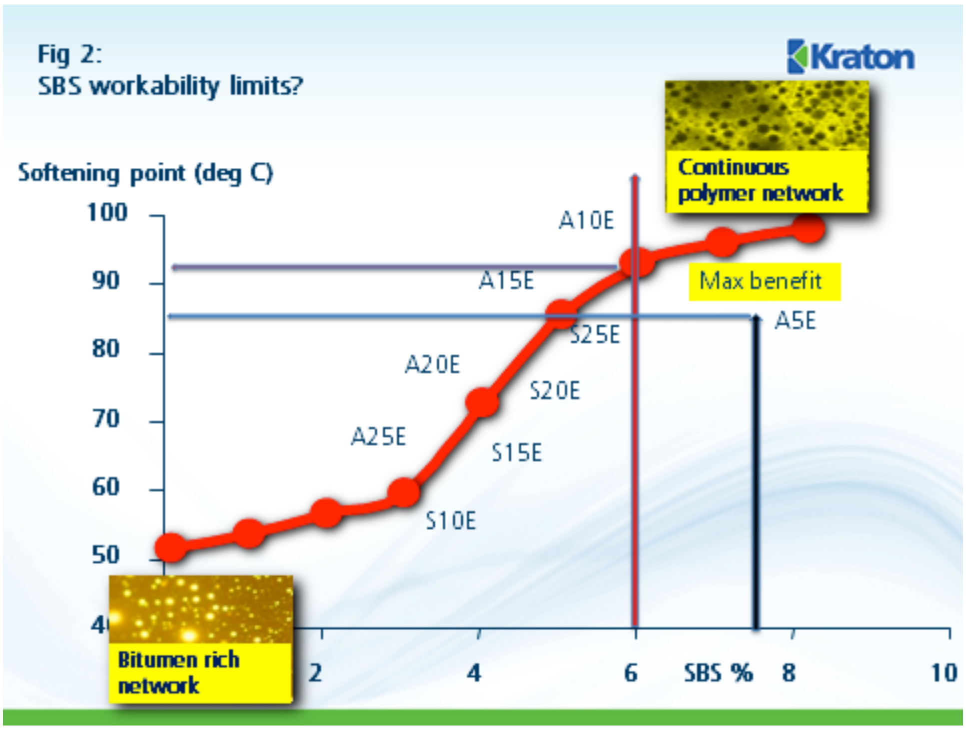
**Abstract**
SBS polymers have been used to improve the properties of bitumen for many years. Kraton Polymers has pioneered a new family of SBS polymers which bring additional benefits and the prospect of a step change in pavement design. This paper will give an overview of the journey that has taken the work from the laboratory to the field and in particular will focus on the various hurdles that a supplier encounters when trying to introduce and implement innovation.

**Introduction**
We have reached a point in the history of road construction and maintenance where we need to radically shift the way we think and do things. Our roads have become too congested and we simply do not have the money or time to keep building new ones or keep maintaining old ones. Albert Einstein was once quoted as saying that the definition of insanity was doing the same thing over and over again and expecting different results. Something has to give. Therefore I think it is timely that this Conference has chosen as its theme "delivering new age solutions". New age solutions are available to help solve these issues but I think the real problem is the "delivery" of these solutions and that is where I will focus my presentation today. Einstein was also quoted as saying: "We cannot solve our problems with the same thinking we used when we created them" and he also said "if you cannot explain it simply, you don't understand it well enough." I hope I can do him proud today and shine a light on the road ahead for all of us going forward.

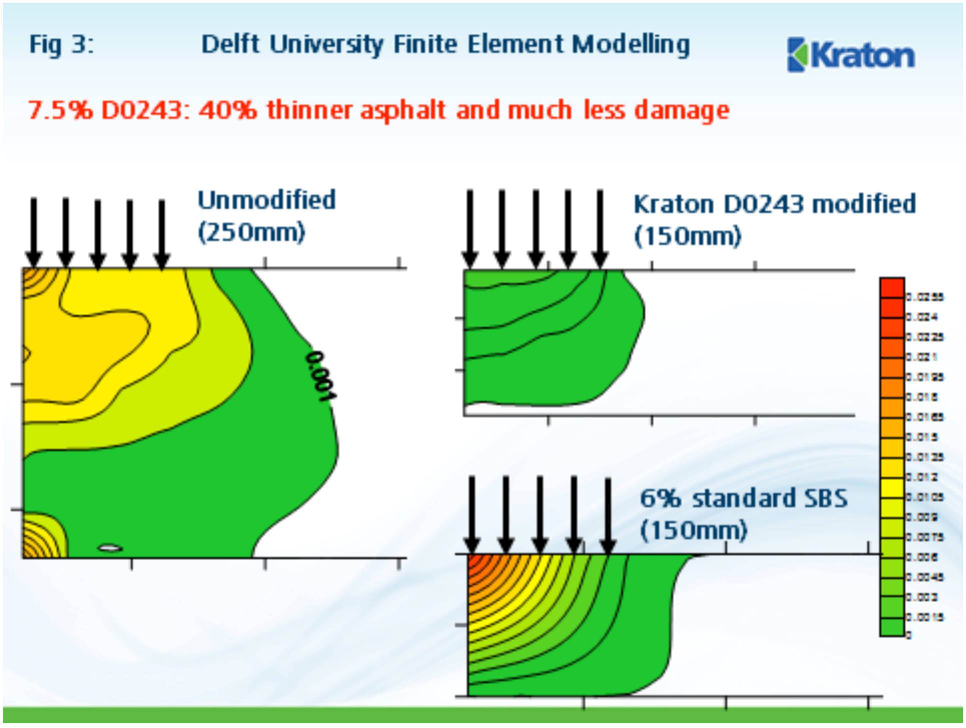
**Problem**
It is generally well understood that the addition of SBS polymers to bitumen improves its properties by making the binder tougher. You can measure this and see this clearly by carrying out various tests like wheel tracking and 4 point beam bending in the laboratory. As the aggregates are held together better and the resulting asphalt mix becomes more elastic in behaviour, we see less rutting and greater resistance to cracking and this means longer lasting roads. In fact, the more SBS you add, the greater the improvements in any bitumen and in any mix. [ Refer Fig 1 below]




However, there is a practical upper limit of how much SBS you can add which is dictated by the increase in viscosity that occurs when you add SBS as it absorbs the oily fractions from the bitumen. This occurs at about 6% addition. Coincidentally and logically, this is where we have set our highest specification called A10E for hot asphalt mix binders and S25E for sprayed seals. Any higher, and the resulting mix just becomes too hard to compact and becomes less workable even if applied at high temperatures.
[ Refer Fig 2 below]



**Solution**
However, all that has changed. About 10 years ago, Kraton Polymers, as one of the world's leading producers of SBS polymers, developed a new generation of much lower viscosity and more compatible SBS high vinyl polymers. We have improved its reactivity and compatibility with a variety of bitumens. We have also improved its stability to heat and oxidation. Finally we have reduced the overall size of the polymer which lowers the viscosity. This means we can now add much more SBS and really take advantage of the improvement in performance without impacting on the workability of the mix. We carried out extensive testing in our own laboratories and then with the Delft University of Technology in the Netherlands using sophisticated finite element modelling to show it was possible to really get this improvement in performance. Then we began wondering, what if we could take advantage of this improvement and reduce the thickness of the pavement. In fact, what we showed was that we could reduce the thickness by 40% without loss of performance. This led us to believe we had found a "New Age Solution". Then we started on the journey of "delivery" of this solution. [Refer Fig 3 below]




**Field Validation**
Firstly, we had to prove out this technology in the field. In 2009, we laid down a section at the NCAT test track in Alabama, USA. N7 section was a full depth asphalt pavement of 140mm consisting of three layers. This was laid using the same bitumen and asphalt mix design as the S9 control section which was a 175mm pavement. [Refer Fig 4 below]

Fig 4: N7 section Pavement composition 140mm vs 175mm (20% red)

| layer | Wearing<br>Pen 80/100 | | Binder<br>Pen 30/40 | | Base<br>Pen 30/40 | |
|---|---|---|---|---|---|---|
| Section | KRA | ref | KRA | ref | KRA | ref |
| Thickness, mm. | 25 | 30 | 53 | 70 | 63 | 75 |
| NMAS, mm | 9.5 | 9.5 | 19.0 | 19.0 | 19.0 | 19.0 |
| % SBS added | 7.5 | 2.8 | 7.5 | 2.8 | 7.5 | 0.0 |
| Binder % | 6.3 | 6.1 | 4.6 | 4.4 | 4.6 | 4.7 |
| Air Voids % | 6.3 | 6.9 | 7.3 | 7.2 | 7.2 | 7.4 |

As you can see, we were careful to keep all the parameters the same and in particular the aggregate size. This restricted us to reducing the overall pavement thickness by only 20%. (Remember we had shown in the laboratory that it was possible to reduce it by 40%). We laid a 25mm vs the 30mm control wearing course, a 53mm vs 70mm binder course and a 63mm vs 75mm base course layer. Each layer incorporated the use of a binder which was modified with 7.5% of this new SBS polymer. The control section only used 2.8% of standard SBS polymer in the binder of the wearing and binder courses. There was no polymer in the base course layer.

**Results**

At NCAT, the trucks are loaded to their legal maximum axle loads and run six (6) days a week (Mondays are used for maintenance and carrying out track inspections). This goes on until 10 million ESALs are completed or about two years of continuous traffic. At the end of this period, full diagnostics and forensics are carried out on each track section. Our results were impressive. N7 showed about 4 times less rutting than the control section and parallel lab tests showed this mix had 27 times better fatigue resistance. Neither section showed any cracking in the first cycle. However, almost half way through the second cycle the S9 control section is now showing signs of cracking.

**Further Evaluation**

During the last cycle, another opportunity presented itself when a section called N8 sponsored by the Oklahoma DOT failed. They were looking to push the limits with pavement design on a known weak sub-base. Unfortunately they went too far. They then carried out a standard rehab incorporating the use of a geotextile to see if they could arrest the damage, however as you can see [Refer Fig 5 below]


this failed again within about 4million ESALs. At this point, it had now become crucial to find a solution to allow the other test sections to continue to the end of the cycle. Given the performance of the N7 section next to this, NCAT advised the DOT that they should consider a 125mm mill and overlay using the new Kraton$^{TM}$ binder. This was done and N8 was able to complete the cycle with no issues after 5.5million ESALs. These two case studies were both reported at the last AAPA Conference in 2011. We then wondered how much further we could push this technology. So we decided to sponsor both sections and continue to run them for another cycle. This started in Oct 2012. We have now completed a further 4 million ESALs and rutting is still only about 3mm on both N7 and N8. The control section is now over 8mm and cracks have started to appear.
This indicates that the Kraton Polymers new age solution is well on its way to be proven a success.

**New Opportunities**
Given the promising results of the N8 section, we also began looking into the applicability of this technology in thin overlays for the purposes of pavement preservation where funding prohibits a full reconstruction. In conjunction with the Transportation System Preservation Technical Services Program (TSP2) which is sponsored by AASHTO in the USA, we have engaged in a study which began in mid 2010. The program is contracted to the National Center for Pavement Preservation (NCPP) at Michigan State University. The NCPP is hosting thin lift paving field studies with ten northeast U.S. states and Professor Walaa Mogawer, director of the Highway Sustainability Research Center at the University of Massachusetts Dartmouth to develop a new specification based on Kraton Polymers new D0243 SBS polymer binder in thin lift mixtures containing up to 40 percent RAP. The study plans initially to test materials from Massachusetts and New Hampshire, and subsequently, several other states.

## Hurdles and other issues

In the meantime, closer to home in Australia and New Zealand, in 2009 we set off on our journey and began "delivering the new age solution" to all the state road authorities, contractors, engineering consultants and anyone who would listen. However we quickly heard the various calls, the push backs and the hurdles we had to jump:
"the roads here are different" ; " we need to test in our mixes" ; "we want to see if we can lay and compact it" and the inevitable big question "who takes the risk?"
We then discovered that a binder made with this new SBS polymer did not meet any of the current Austroad specification limits for the various binders. [Refer Fig 6 below]

Fig 6: New binder spec?

Kraton

| AGPT/T190 Binder Property | Sprayed seals | S45R | S35E | S10E | S15E | S20E | S25E | New | |
|---|---|---|---|---|---|---|---|---|---|
| | Hot mix | | | A25E | A20E | A15E | A10E | A5E spec | A35P |
| Consistency @ 60C (Pa.s) | min | 1000 | 300 | 250 | 700 | 700 | 5000 | | |
| | | | | 600 | 600 | 5000 | 6000 | 10000min | 2000 |
| Stiffness @ 15C | max | 180 | 180 | 140 | 140 | 140 | 95 | | |
| Stiffness @ 25C | max | | | 45 | 35 | 30 | 30 | n/a? | 120max |
| Viscosity @ 165C (Pa.s) | max | 4.5 | 0.55 | 0.55 | 0.55 | 0.55 | 0.8 | | |
| | | | | 0.6 | 0.6 | 0.9 | 1.1 | 1.0max | 0.6 |
| Softening point deg C | band% | 55-65 | 48-56 | 48-64 | 55-75 | 62-88 | 82-100 | | |
| | | | | 52-62 | 65-95 | 82-105 | 88-110 | 85min | 62-74 |
| TR @25C, 30s | band% | 25-55 | 16-32 | 22-50 | 32-62 | 45-74 | 54-85 | | |
| | | | | 17-30 | 38-70 | 55-80 | 60-86 | n/a? | 6-21 |
| | | | | | | | | | |

Should look at rutting and fatigue specs for each of the mixes

As you can see, we have a very low stiffness number in the specification which forces binder producers to use C170 bitumens and high levels of oil to soften the bitumen further to meet this spec. This was done because it is assumed that in wearing courses fatigue resistance is needed. However, the consequences of choosing these softer binders is that rutting is now seen as a problem. So the next big question came up "how can we specify this in a tender without mandating that Kraton™ modifiers be used?" My answer is simply remove the stiffness specification and introduce a minimum fatigue performance specification based on the mix rather than the binder.

## Implications for Pavement Design

We learnt that the software programmes used to design pavements do not take the improvement in fatigue into account. They basically focus on modulus as the criteria for determining the thickness required. So the designers told me they could not take advantage of this innovation. [Refer Fig 7 below]

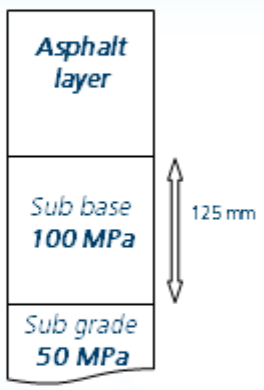
**Fig 7:** **Austroads Pavement Design Guide AGPT02-08 (part 2) page 72**

Modulus adjustment factors for various binders based on comparison with C320 bitumen

- Styrene-butadiene-styrene (6% SBS) A10E 0.70
- Styrene-butadiene-styrene (5% SBS) A15E 0.75
- 25 parts granulated crumb rubber A40R 0.75
- Styrene-butadiene-styrene (3% SBS) A20E 0.80
- Polybutadiene (PBD) A25E 0.90
- Multigrade 1000/320 1.00
- Ethylene vinyl acetate (EVA) A35P 1.25

In fact, as you can see in the Austroads guide AGPT02/08 to pavement technology, it has determined adjustment factors when using SBS modified binders in the mix. These are misleading, as they compare the modulus of an asphalt mix with a C320 binder with one using an A10E binder which is forced to be made with C170 bitumen and a high level of oil to meet that low stiffness spec. Is it any wonder, the modulus is 30% lower? However, if one makes a binder using a C320 bitumen and adds SBS but no oil, we get a modulus which is only 10% lower. Furthermore, if we take into account the improved fatigue from using SBS in the binder, we see this makes an enormous difference to the pavement design. Let me show you by way of an example. [Refer Fig 8 below]

**Fig 8:** **Austroads Design calculations ??**
**develop own fatigue equation with a well known method**




**Currently Austroads says allow 30% loss in modulus with A10E (6% SBS) PMB and no fatigue benefit**

Using Melbourne climate , 10 million ESALs

Standard asphalt mix using pen 30/40 bitumen:
Stiffness at 20C : **8900 MPa**

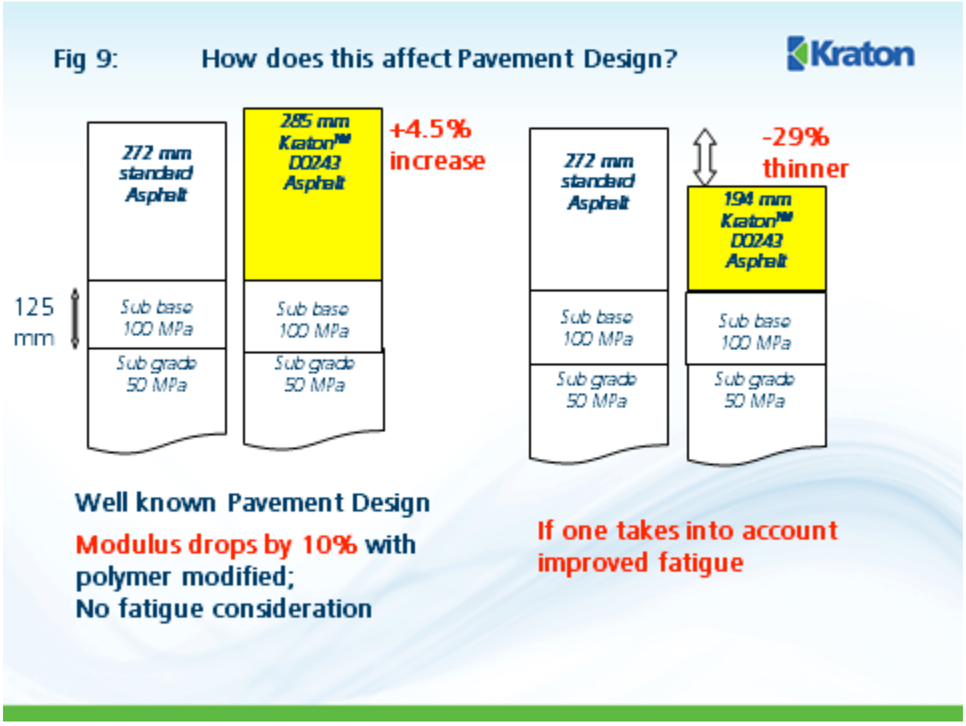
Fatigue equation: $N = 6.10^{11}x^{-3.36}$

Kraton D0243 modified mix:
Stiffness at 20C: **8100 MPa**

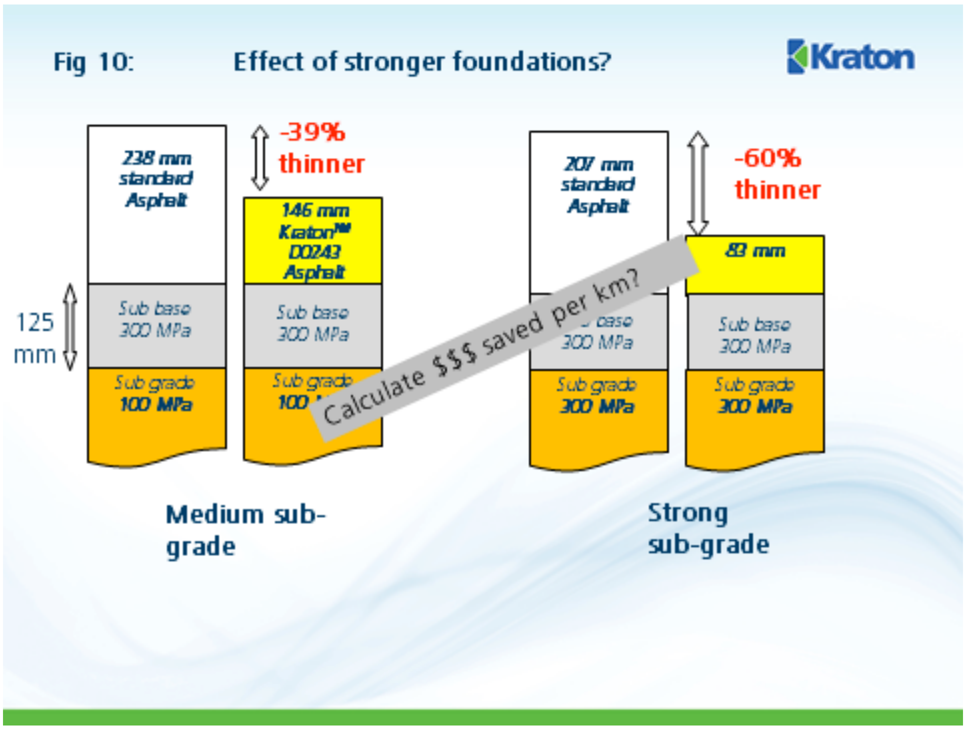
Fatigue equation: $N = 9.10^{18}x^{-6.17}$

*Only 10% loss in modulus*
*What difference does fatigue make for the design?*

If we now use the data and create our own Fatigue equation, we can compare the resulting pavement design. [Refer Fig 9 below]




As you can see, if we follow the current Austroads guide, and take into account the 10% reduction in modulus, we finish up with a 4.5% thicker pavement even though we have a much more fatigue resistant mix. However, if we take into account the improved fatigue, we get a 29% reduction in thickness. If we look at stronger foundations the results are even more impressive [Refer Fig 10 below].



These are in line with what was predicted by the finite element study at the Delft University of Technology and seem to have been proven in the field at the NCAT test track. I am glad to see there is an ongoing study by AAPA called "Asphalt Pavement Solutions - For Life" which started in 2011 which hopefully will address some of these shortfalls.

**Case Study 1 – Napier Port, NZ**

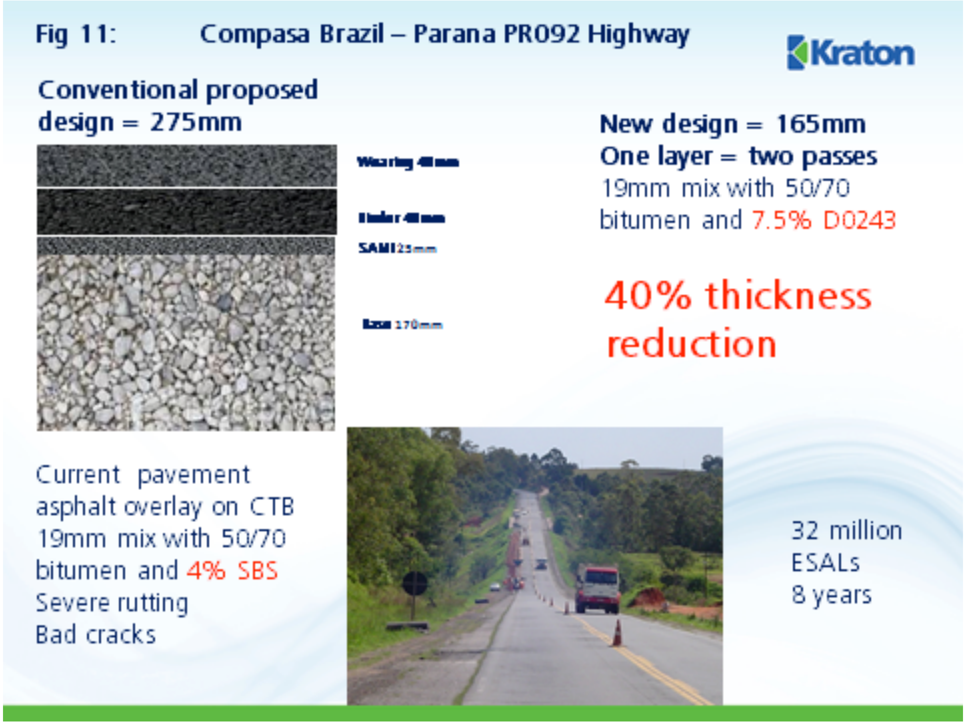
Luckily we had one early adopter in New Zealand in Higgins Contracting who was prepared to try it out. They had been approached by the Napier Port to rehabilitate the pavement used by the container forklifts which had caused 50-80mm rutting and this had become a major problem to their ongoing operation. A new pavement was completed in Sep 2010. Now some three years later the pavement looks as good as the day it was laid. Since then, they have used the technology on a number of small projects and it is slowly gaining some acceptance.

**Case Study 2 – Pennant Hills Road, Sydney, Australia**

In Australia, in early 2011, the RMS decided to carry out some of their own testing and they were so impressed with the lab results that they came up with a proposed new specification which they have dubbed A5E. They then agreed to undertake a "lay down and compaction trial" in Penrith in Nov 2011 to validate what we had seen elsewhere in the world. This was successful and we were then told that a commercial field trial would take place to see how it would perform on Australian roads. We waited patiently for a further 15 months, and on Feb 18, 2013 in conjunction with Downer we are now monitoring a section on a very busy part of Pennant Hills Road near the M2 turn off which has been resurfaced in a head to head trial versus a conventional A15E binder. This asphalt overlay is over a variable concrete base where the slabs have moved and cracked. This is certainly one hell of a test. The word is that if this technology proves itself, it "may" be adopted as a fix for other sections of road in the future. There is even some thought to looking at using it to reduce the thickness of the wearing course and save money up front.

**Case Study 3 – Brazil**

Elsewhere in the world, we are starting to see some large scale projects moving into the "delivery" phase of delivering new age solutions. One in Brazil [Refer Fig 11 below]




which has been documented is a section which has been laid using a 40% reduction in design thickness and has been successfully running for more than 18 months.

**New opportunities**
We are also seeing this same polymer being used successfully in highly modified emulsions and novel microsurfacing treatments bridging the gap with hot mix asphalt. That's a whole new story that is emerging. Watch this space. Finally, as our Company tag line says, we at Kraton Polymers continue to Give Innovators Their Edge.

**Conclusions**
I trust that I have taken you on an interesting journey and opened up potential new age solutions in the construction of new roads and the maintenance of existing ones. It is now possible to take full advantage of the benefits of adding SBS without any workability limitations. Amidst and faced with all the hurdles outlined in this paper, one could have easily given up…but we believed in the technology and were determined to see it through. We believed the potential money that could be saved up front and ongoing would be significant enough to get road asset owners to consider it. It is also the right thing to do in saving our precious resources. One estimate has shown about $1 million per highway km can be saved. However, realistically, the adoption of this technology for full depth pavement thickness reduction is probably a few more years away yet as we grapple with the specifications and the risks. Maybe some of the new proposed PPP's and new ways of funding roads will allow scope for new innovations like this. It seems Einstein was right when he said that "it has become appallingly obvious that our technology has exceeded our humanity".

**Acknowledgments and Disclaimer**
There are so many people I would like to acknowledge that have been part of this journey which really has only just begun. My thanks go to all concerned. Finally as a USA public listed company we request that you please reference the comments in this paper with our disclaimer below.

**References**

Austroads AGPT/T190: Specification for polymer modified binders
Austroads AGPT02/08: Guide to Pavement Technology
NCAT Report August 2102 “Field and Laboratory Study of High Polymer Mixtures at the NCAT test track- interim report” by Dr David Timm et al.
ARRB 2006 Conference paper “Asphalt Performance Testing and mix design – a way forward” given by Ross Paul.

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