Oral History Program

Pavement recycling & stabilisation

SUMMARY REPORT

Researched and written by Cinetel Productions

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About this oral history...

Oral history has been described as "a picture of the past in people's own words". It is based on stories by people who were involved in life's events, told in their own, passionate words. It adds to the official written history and gives us a more intimate and personal perspective on how, when and why things happened. Oral history is a means of communicating how individuals perceived and dealt with challenge, achievement and failure. It often reveals the unsung heroes, those actually responsible for innovations and important changes, and provides them with an opportunity to evaluate their actions in a wider occupational, social and political context.

The RTA Environment Branch established its Oral History Program in 1997, to investigate various topics of historical interest. *Pavement recycling and stabilisation* is the ninth thematic oral history to be undertaken as part of the Program. As with previous projects, this oral history did not seek to present a definitive history of developments in this field, rather it involved a recounting of interesting stories and insights, told by those involved.

The project was based on 28 hours of digitally recorded interviews with 23 participants - former Department of Main Roads staff, former and current RTA staff, a Transport Authority executive, a Local Government engineer, operators and managers in the pavement stabilisation industry and an academic. It discusses pavement design and construction practice, the various methods of pavement stabilisation employed, the role of Local Government, the ongoing development of specialised equipment, the use of additives and recycled materials such as slag and fly ash, and the efficiency gains which flowed from targeted research and effective cooperation with industry.

This report is a summary of the key themes and findings revealed in the course of research, investigation and interviewing. It is one part of a project that includes the original interview tapes, logs, photographs, research materials and an edited double-CD compilation. Compiled excerpts from the original interviews may be accessed on the RTA website at www.rta.nsw.gov.au. Click on "Environment", then "Heritage", then "RTA Oral History Program", or simply type "oral history" in the Search window.

The author would like to acknowledge all who contributed to this oral history - the 23 interviewees named at the end of this document and the staff of the RTA Environment Branch who assisted with the project.

Contents

Stable/adj/, not likely to fall or give way, as a structure, support, foundation, etc.; firm, steady; able or likely to continue or last; enduring or permanent, not readily decomposing, as a compound; resisting molecular or chemical change.

(Macquarie Dictionary definition)

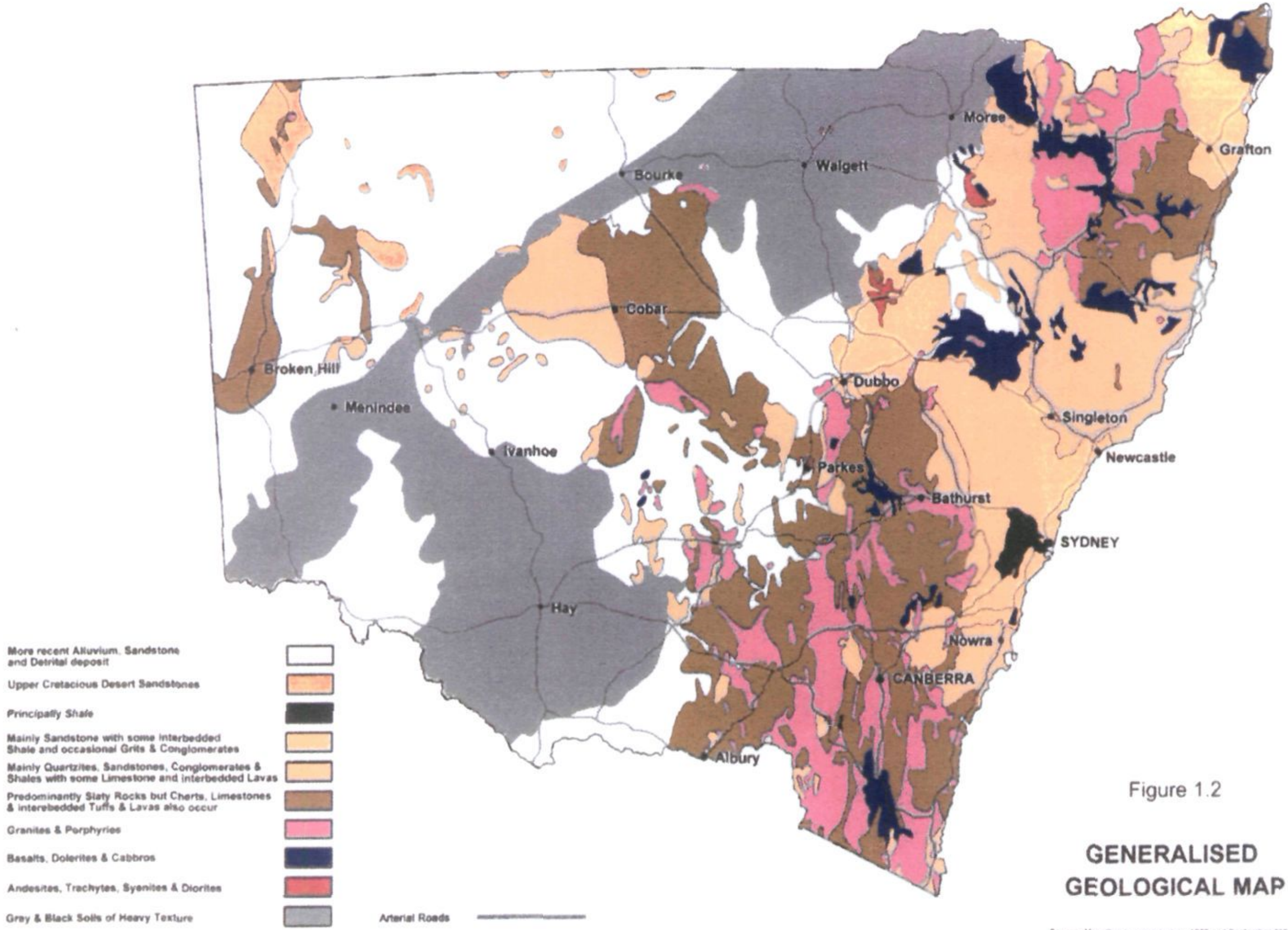


Figure 1.2

GENERALISED GEOLOGICAL MAP

Source: Main Roads Journals June 1956 and September 1959

From soil and clay to something more durable

Right back to the distant tribal past, mankind longed for stability in his and her world – something solid to put one's feet on, so Ihor Hinczak, a private consultant and principal of Cementech Pty Ltd suggests:

> 'I think stabilisation probably first started off with the first man who stepped outside his cave and went ankle deep into sludge, so he decided to do something with it, so he probably found some ash under the pot he was cooking his dinner in and threw it outside and found that it made it harder, so that's what he did from that day. I think it's part of evolution and it's what man wanted as durability.' (Hinczak, Tape RTA-PRS:FH20, Side A, 18:44)

The Romans are reputed to have been the first serious users of stabilisation when they made a discovery, as Phil Walter, Manager, Flexible Pavements at the RTA Pavements Branch describes:

> 'Well, stabilisation goes back to the early Roman times when the Romans found that if they used crushed sea shells and sand, which they found to be pozzolanic coming out of Mt Vesuvius volcano they were able to form a cementitious product.' (Walter, Tape RTA-PRS:FH2, Side A, 03:02)

> (The Romans) built roads by adding lime to various things and also adding pottery shards as aggregates... and they would have the lime reacting with the clay and the other materials forming - these calcium illuminate hydrates and calcium silicate hydrates - which were the precursors and are the skeletons of Portland cement minerals. (Hinczak, Tape RTA-PRS:FH20, Side A, 18:14)

Warren Smith, a stabilisation industry contractor adds:

> 'I think the road behind Hadrian's Wall in the U.K. has been lime stabilised, so it does go back a long way.' (Smith, Tape RTA-PRS:FH3, 06:35)

George Vorobieff, Executive Director of the Australian Stabilisation Industry Association, remarks on the more recent history of stabilisation:

> 'It appears that the little documentation written on the history of stabilisation tends to steer you into the area of soil/cement stabilisation and the United Kingdom and the United States and in fact, Germany just before World War II were somewhat leaders in this area, and if you look back at the literature in the US, it seems that the first projects on record in the United States, involving this soil and cement process were built in 1922 in South Dakota and Iowa and a lot of people, I suspect, considered it as an el-cheapo process – almost were dismissive of a technology worthy of documenting.' (Vorobieff, Tape RTA-PRS:FH22, Side A, 01:17)

The Australian history of stabilisation also has strange beginnings:

> 'Through the 1920s, 1930s some of stabilisation early works were done with wool from sheep – they used that to stabilise pavements where they had pavements that were failing through very wet, boggy conditions, just the wool from the sheep was enough to form a mat, with soil added to the top of it and that actually provided a tensile layer. But bear in mind in those days too, there were a lot of sheep around

> and wool wasn't all that expensive, so the farmers didn't mind sacrificing some of the poorer quality wool.' (Walter, Tape RTA-PRS:FH2, Side A, 05:10)

It was not until the Second World War that the first machines for stabilisation were introduced to Australia:

> 'They made, what they call 'Beef Roads' up north and they were really defence roads. To get things up north as quickly, if we're going to get invaded, and the Americans introduced a lot of stabilisation. I did a fair bit of stabilisation when they took a lot of all these Islands over in the War and they made a lot of airstrips and infrastructure just around the camps, using stabilisation. They'd just come in and cement stabilise the pavements really quickly.' (Smith, Tape RTA-PRS: FH3, Side A, 22:34)

Paul Ritchie, an early Local Government stabilisation engineer remarks:

> ('The Americans) developed, not only the process but they developed a machine called the P&H machine, which had a triple rotor mechanism and was like a very big tractor on tracks, and it was connected to the water carts – to add the water, and it had a triple rotor mechanism, which gave it a triple mix – a very efficient mix.' (Ritchie, Tape RTA-PRS:FH28 Side A, 28:05)

The P&H machines proved to be very suitable for the task, but when war ended, the Americans handed them over to the RAAF who had no further use for them, so the machines were largely abandoned. Then an enterprising company, Stabilising Australia (later to become Stabilex) had the thought that perhaps those machines could be used to stabilise roads and bought them from the RAAF. At that point, stabilisation of road pavements in Australia began in earnest.

During the 1950s and 1960s, when stabilisation was still a new and untried concept, Stabilising Australia tried to promote the process to Councils and local road authorities:

> 'I can remember seeing one... I'm not sure if it was a movie, but certainly slides of a job being done at North Sydney Council in the mid to late fifties, where they had a P&H and they were stabilising a road by recycling a road in North Sydney.' (Ritchie, Tape RTA-PRS:FH28, Side A, 30:45)

Ihor Hinczak recalls how rudimentary stabilisation technology was in the 1950s, using the P&H machines:

> 'You had patches where there was no stabilisation and you got rutting – subsequently there were patches where the material was so hard you couldn't break it with a hammer. It was quite a while before someone decided to put Portland cement through a lime spreader and spread the cement more uniformly, rather than putting cement bags out and saying 'We'll have so many bags per square yard' in those days and get the rotary hoe to break the paper sacks up and mix them up with everything else. There were some instances where there were paper sacks sticking up out of the stabilised pavement in those days, and people didn't like them, particularly the engineers who viewed them.' (Hinczak, Tape RTA-PRS:FH20, Side A, 22:23)

It was not long before engineers noticed shrinkage cracking in their cement-stabilised pavements as they began to fail, one after another:

Spreading cement using bags, 1970s

Modern spreaders delivered better uniform spreading than traditional tipper trucks and bags of cement. These units were designed in Australia

> 'Some of the strengths we were getting out of these stabilised pavements were quite high…..some of these cracks were anything up to 10mm or 15mm in thickness. That meant that the water, if it actually did rain, would go down through the cracks and quickly into the subgrade – it would wet up the subgrade, you'd lose support in the lower layers, which would then increase the rate of failure of the base material. (Walter, Tape RTA-PRS:FH1, Side A, 14:34)

In an attempt to stop the failures, cement trials were carried out:

> The cement trials were the first lot – mostly done in the middle nineteen fifties, and the behaviour of those was such that by the nineteen sixties, people had turned away from using cement stabilisation because of the failure rate. In the 1960s they introduced lime, only because a lot of the non-standard materials suffered from combinations of lack of grading and plasticity index. And the idea of the lime was then to reduce the plasticity index to an acceptable level, and a lot of those early trials were very thin layer stabilised – in those days six inches – 150 mm by today's standards, and because they were so heavily bound it was just like a sheet of glass on an innerspring mattress, that when the traffic loadings increased over the years, these materials tended to fatigue crack and fail. (Walter, Tape RTA-PRS:FH1, Side A, 09:46)

Further trials were held in the State's far west to solve soil plasticity problems in black soil country:

> Up at Bourke, going towards Byrock on the way to Nyngan, there was a length there of a couple of kilometres where we had a black soil project and the idea there was to stabilise black soil from the sub-grade right through to the base layer and make pavement materials out of black soil. Black soils have a fairly high plasticity index – roundabout 60% and the materials have a very high shrinkage – roundabout, say 25%. Out in the black soil areas they reckon they could even lose a sheep down the cracks when they develop in the ground, they're so wide, and they go down for a depth of maybe 10 or 15 metres – these cracks, into the sub-grade, so they're quite extensive cracking. These materials suffer when inundated with water into swelling. The huge swells can actually cause the pavement to lift anything up to 300mm in places, and then when the moisture content dries back, those pavements return, basically into their former position. So these pavements are potentially moving up and down, and in these areas here, we have a lot of trouble with concrete structures like culverts and that. These culverts are often referred to as jumping culverts where they actually pop up out of the road and form a bump. We're looking to build a pavement from sub-grade up to base level using black soil, which would be stabilised with lime and we formed a fairly good pavement, because during the construction they had some very heavy rains and the black soil either side of the road structure was actually eroded away and what they were left with was just the block of stabilised pavement between, so they actually reformed the shoulders up again. So that actually proved that during very wet weather these sorts of pavements would hold together without erosion. That pavement to my knowledge is still there today and I only spoke to somebody about two years ago and they said it was still operating quite successfully. (Walter, Tape RTA-PRS:FH1, Side A, 28:08)

So what exactly is stabilisation? George Vorobieff clarifies the methods used:

> Stabilisation techniques fall into two categories. One is a plant mix arrangement and the other category is an insitu arrangement. Plant mix is using a stationary plant where all the road materials and the binders are put into hoppers and weighed and

Two ways of adding cementitious binder

> mixed in a pugmill and extracted and stockpiled and then taken back to the site. In insitu we tend to spread the lime or cement or spray the bitumen and mix that insitu, or in place, and then compact the material. (Vorobieff, Tape RTA-PRS:FH22 Side A, 18:05)

There are two types of stabilisation: Mechanical and Chemical. Geoff Youdale was General Manager, Technology Development at the RTA in the 1980s:

> 'Stabilisation has primarily two objectives. You can have what's called Mechanical Stabilisation, where you might just have a material whose grading is deficient and you need to put something in it so you can compact it and make it work, or there is a need to improve the material strength and its moisture susceptibility. In which case you generally add a chemical binder to it, or in some cases polymer or bitumen to it, to either make it stronger, more impermeable, or improve its structural properties.' (Youdale, Tape RTA-PRS:FH32 Side B, 53:36)

Ken Porter is now Senior Project Manager, Private Infrastructure with the RTA. He explains the modern process:

> 'Stabilisation is a process that developed because you didn't have perfect gravels. We don't build our roads out of dirt and we don't build our roads out of bitumen. We use bitumen on the surfacing of rural roads to hold the stone and it's only a surfacing treatment. The actual strength of the road to carry the truck axles – which are the heaviest axles we carry, is built in the interlocking particles in a matrix of what's called a road making gravel, and road making gravels are not dirt, they're very specialist materials - they can be found occurring naturally and extracted from the ground, but the good deposits soon become in short supply. So if you're working, building roads in an area where there's not a good gravel quarry nearby for some many kilometres, it's going to cost you a lot of money to haul it in over road, from maybe two or three hundred kilometres in some cases – out west there's not a lot of good gravel. In those circumstances, as an Engineer, you use the resources to say – well how can I improve what I've got? Stabilisation was a technique of improving what you've got by adding a cementitious compound or a bituminous compound to add a binder. Normally we'd start by considering stabilisation as a life extension of a pavement, so it would be a pavement that doesn't have a failure here and there, which you could patch out, but a pavement that is largely deformed, rutted or cracked with what we call crocodile cracking, so it's at the end of its design life. The roads are actually designed for a number of passes of truck axles – so let's say we take that as the first dilemma. So we look at this road and say – well, what are we going to do with it? If we were at the gate of a quarry with perfectly good road-building material we wouldn't stabilise, we'd overlay the pavement, because that would be the cheapest way to do it. It's not often the case, so the next thing to do is to say 'let's consider stabilisation.' We would sample the pavement to find out what is there. If there was 150mm of road base – that's the top layer – the best quality gravel that's on the top that's sort of causing the problem, or if it is failing, the records might tell us that and then we would take some samples by coring into the pavement and taking them back to the laboratory for testing. Given the material, and it's what we call its grading of course, which is the gradation of the sizes of the particles that make up the existing gravel, we could then have a bit of a guess from experience, I suppose, at the amount of cementitious product we might have to add in a stabilisation. We would then consider our construction method and the traffic. If we're going to get a clear go at this, if we can close the road during working hours for a day and put people on a bypass, well then we can bring in some big equipment and we can have some reasonable access and some reasonable productivity and we

can get the stabilisation done fairly quickly, so we might choose a particular binder that sets fairly quickly. If, however, we've got to work under traffic – we're on some parts of the Princes Highway down the South Coast or we're on some parts of the Great Western Highway where there's not a viable alternative for traffic, and we've got to work on one side of the road while we flag the traffic over to the other side, and occasionally we've got to put the traffic on the dirt while we move barriers and things – well then it's going to take us a lot longer and we're going to need a slower setting stabilising agent because if the material starts to set too early we can't then compact it fully and we can't get a strong pavement. This would influence how much slow setting cementitious material we'd use like pozzolans – like Fly Ash or granulated blast furnace slag and what we would blend that with, in terms of hydrated lime, etc. Given that, we could then do some laboratory tests on samples. We have to take bigger samples out of the road - we need a bit of material; we need about 50 kilograms of material to play around with and we can configure a matrix test whereby we look at different percentages of different stabilisers with the same granular material, and we test their unconfined compressive strength after they're compacted in moulds and tested in a machine. We can do that at different times of testing, as well to check the rate of gain of strength, so that we know we're going to get the right working period.' (Porter, Tape RTA-PRS:FH5, Side A, 11:15 & 16:11)

Local Government takes up the challenge

By the late 1960s, with Sydney's expansion beyond the perimeters of the established suburbs, previously rural areas were becoming urbanised and the condition of their roads was not up to the standard required. As one housing estate after another sprang up, pressure began to build for good roads with kerbs and gutters. Paul Ritchie, a young Local Government engineer at the time recalls the state of Bankstown's roads in 1968:

> 'The sealed roads weren't too bad, but they had a lot of unsealed road shoulders with no kerb and gutter and they were spending a lot of money on grading of those road shoulders to remove the drop offs at the edge of the seals, because that was in a fully urbanised area. Then they had some other areas, which had been developed largely by the Housing Commission, plus some of their own roads, that had been developed in about the 1950s – most of the road pavements running 150mm to 200mm deep. A lot of them constructed of materials that these days we would only put – if that – in the sub-base, let alone in the base, and so they were failing, they were also failing. So they had two problems – they had a lot of road shoulders that they wanted to build to give the residents full width roads, kerbed and guttered, but they had a group of other roads that were prematurely failing because of the traffic increases in those days and the very light construction of which they'd been built and quality that they'd been built to.' (Ritchie, Tape RTA-PRS:FH28, Side A, 16:50)

Tom Wilmot is a stabilising industry contractor and became involved with Bankstown's stabilisation project as a contractor in the early 1970s:

> 'Bankstown were looking for a way to successfully seal a huge road network which consisted of a central strip of bitumen, probably just wide enough for one lane and two roughly formed unsealed shoulders, so in the winter it got very wet and in the summer it got very dry and dusty and, largely due to the efforts of Richard Holland and the engineers at Bankstown, they developed the concept of stabilising their shoulders, starting with as low as four inches in depth, though the bulk of the work was done at six inches, or 150mm and then they were sealed with a light one coat bitumen gyp seal.' (Wilmot, Tape RTA-PRS:FH18, Side A, 20:55)

However, before the stabilisation program had begun in Bankstown, there had been some doubt that the process would be successful because of the many failures with insitu stabilisation that had already occurred:

> 'There was a great deal of cynicism and doubt in everybody's mind that it would work. I can remember the Deputy Engineer there, and the Chief Engineer at Bankstown not believing in it. They were quite cynical that the process would work, but they thought, we've got to give it a go, because we're not getting anywhere at fulfilling the residents' needs in terms of the condition of the sealed roads and the condition of the road shoulders. I was a bit cynical with the whole process too – although I wasn't very experienced, I was only in my mid twenties, but I'd learnt a bit in my course about stabilisation and I'd learnt about designer road pavements and I thought what they were doing wouldn't work, because you know the theory from your course, but you don't know the practical. So that was a very great learning experience, which I probably didn't recognise initially myself where it was heading, but in retrospect it was great. (The stabilisation program) was very successful and Bankstown extended it through most of its shire. From there, we also started to do

P&H stabiliser at work on a typical Bankstown street, 1970s

Close look at the mixing chamber of the P&H

> what we termed full road construction, which was to do the central pavement as well as the shoulders in roads where they required strengthening.' (Ritchie, Tape RTA-PRS:FH28, Side B, 35:23)

Tom Wilmot recalls how Bankstown actually went about stabilising their roads:

> 'A Council would say we want the section done from house number 1 to house number 32. We would arrive on site and we would shape the road to correct any irregularities in the existing roadway, spread the cement, mix it with the P&H stabiliser attached to a water cart, so we'd be ejecting water at the same time. The resultant blend would be a relatively dry mix of the existing roadway, the cement and the water. We would then compact that immediately and try and complete our compaction within an hour to two hours at the most and then give the road a final shape with the grader.' (Wilmot, Tape RTA-PRS:FH18, Side A, 30:37)

After stabilising the roads of Bankstown, Paul Ritchie moved to Blacktown Council, which then had the reputation of having the worst roads in Sydney:

> 'They were basically a rural council on the edge of the Sydney developed area which all of a sudden had bloomed into an urban area. Consequently, their old rural central roads were now taking a gigantic traffic load, their old residential streets had been built by rule of thumb – 150mm of road base, and they had failures and potholes everywhere. You would be lucky to drive a road in that area in Blacktown without hitting a pothole.' (Ritchie, Tape RTA-PRS:FH28, Side B, 50:35)

For Ritchie, the situation was one of almost total desperation:

> 'The roads in Blacktown were so bad that we had to bite the bullet and I had to say that in some cases, that road really wasn't good enough for stabilisation, but we had no alternative - we went in and stabilised it, knowing then that we were lucky to get six to ten years out of it because there was just not the money to go into these roads and reconstruct them.' (Ritchie, Tape RTA-PRS:FH28, Side B, 53:10)

Ritchie recalls the condition of one such road, Sutton St., in Blacktown:

> 'It was a typical little residential street, carrying a bus. It was terrible – we stabilised it in 1976, knowing it wouldn't last. Roundabout ten years after – we were over the problem then, by the way, we'd got the roads in shape – that road had fallen to pieces, absolutely fallen to pieces. The kerb and gutter in that road had all heaved, gone up and down – up to 100mm vertical movements in the road, and the road was in atrocious condition, it was absolutely horrendous. We went in and reconstructed that road properly – the clay was plasticine: you could actually put your fingers into the clay, it was that bad. We went down about half a metre or more in that excavation- we struck every water service in that road, in every house on one side. The cost of that job would have been five to eight times the stabilisation cost to do that road properly. In 1974/75, Council could not have afforded to spend that type of money on one residential street, so I still argue what I did on that road was right. Yes, it didn't last, but at three or four dollars a square metre in those days to do that road and hold it for eight to ten years was the right strategy.' (Ritchie, Tape RTA-PRS:FH28, Side B, 53:53)

Following the success at Bankstown and Blacktown, stabilisation soon spread to other councils:

> 'Warringah Council, Rockdale – certainly Brisbane Council took it up, I think, in the eighties and by the nineties had done a million square metres of recycling by stabilisation. They were doing huge quantities. They had their own manual written out on stabilisation, so they were – to my knowledge, and still are the biggest council in Australia, which does stabilisation or recycling of road pavements by stabilisation.' (Ritchie, Tape RTA-PRS:FH29, Side A, 09:57)

Looking back, Ritchie evaluates the Bankstown and Blacktown experience:

> 'What Bankstown did in the late sixties was actually the whole progress of stabilisation - certainly in New South Wales...... I think we've got to give great credit to Bankstown and those engineers that were there at that time, at trying the process, at experimenting with it, trialling it and testing before and after. I think we can all thank Bankstown a great deal for what they did in the sixties. Without that groundbreaking work of trial and testing, I don't think it would have gone anywhere, unless somebody – I suppose I can't say that – somebody else would have picked it up eventually and tried it and pushed it and experimented with it and I'd imagine surely other organizations throughout Australia, whether it be Brisbane City Council or main road organisations must have learnt from all of that. I know the stabilising companies themselves learnt a great deal from the whole process, so it wasn't just the Councils. The operators and the managers of those companies, of Stabilex and the others learnt a huge amount from those trials and experiments that were done at Bankstown.' (Ritchie, Tape RTA-PRS:FH29. Side B, 36:50)

The DMR and the main roads network

During the 1960s and up to the mid 1980s, the Department of Main Roads NSW – the DMR – reigned supreme. It had the sort of clout that other government departments could only dream of. Its primary business was road building and engineers were the driving force in the organization, as David Dash, former Manager of the Pavement Branch at the RTA recalls:

> 'It was a rapidly developing organization - extremely hierarchical - engineers ran the show......... It was field offices all over NSW. These offices had up to 80 to 150 people - workshops, clerical - and they were interesting places to be in, in interesting towns in many cases. They were spread right throughout NSW.' (Dash, Tape RTA-PRS:FH30, Side A, 04:59)

The DMR employed its own day labour gangs. Ihor Hinczak, on visiting the Grafton Works Office, made his own observations on their work practices:

> 'They had a start period, they had a smoko period, they had a lunch period, they had another smoko period and they had a going home period, and in the country of course, without being too disrespectful, people didn't want to work overtime because it chewed into their beer drinking time. So these poor engineers had to try and use cement to do pavement stabilisation in these periods that were available to them. There were some sections of pavement done where they were halfway through rolling it and it was smoko time, so everyone stopped. Of course after smoko it was the wrong profile, so you often had to cut it out and start all over again, and this could happen two or three or four or five times.' (Hinczak, Tape RTA-PRS:FH20, Side A, 24:43)

The problem that concerned the DMR most during the 1970s was the Hume Highway. Greg Harris was a grader driver on the highway then:

> 'A lot of the highway from Tarcutta to Albury - there was potholes and guideposts. The actual width was very narrow, because it didn't have edge lines or anything like that on it and they were at that stage when they were actually trying to widen it a bit. They talked about an area just north of Holbrook and it was stabilised – they said it was an old steam-driven machine that had actually done the stabilising - and it was very badly cracked and in our maintenance we were always pouring emulsion down these cracks.' (Harris, Tape RTA-PRS:FH15, Side A, 12:33)

The condition of the highway was atrocious:

> 'We had the bad areas, like they used to call Tarcutta Narrows, which is a very narrow road, very winding, trees and that, very close to the edge of the road and that used to attract a lot of truck accidents and then down at the bottom end, we had what they called Billy Hughes' Bend – that was another area, it had a big S-Bend going over a railway line and that used to get a few accidents, and they were just in the process at that time of realigning that and then they put a new bridge in there – that's where it is today – and we had another disaster there later on when the abutments to the bridge collapsed and we actually had to close the Hume Highway at that point. The reason (for the collapse) was moisture in the ground and vibrations from the main Sydney-Melbourne railway line underneath it. Well, it was closed for a month - it was pretty major - they drove guardrail across the highway and closed it

> and diverted the traffic to Old Sydney Road.' (Harris, Tape RTA-PRS:FH15, Side A, 15:16)

Harris recalls a section on the Hume Highway near Tarcutta:

> 'That was a patch we'd done. It started off being a 150-metre patch – it wasn't going to take long, but when we actually excavated, it had a lot of cement-stabilised patching in it and it actually took a dozer to get the big slabs out. It was a real wet area, near a creek. We opened that up and started to do the stabilizing and it was nearly six months later before we sealed it – it was open all winter and we were nearly at the stage when we were towing vehicles through it. The job took six months, but was originally only going to take ten days.' (Harris, Tape RTA-PRS:FH15, Side B, 38:15)

In the 1980s, Brian Hanson worked on the Hume Highway, which was then undergoing rehabilitation by stabilisation:

> 'Wagga Hill is a section of the Hume Highway near the intersection with the Sturt Highway. Back in the eighties that was undergoing a lot of rehabilitation and restoration to keep it trafficable and in that process there was a lot of stabilisation done in the surface layer, using cement, and possibly due to the cement content being too high and a combination of the subgrade being too weak, the base material, the surface material pavement actually broke up into blocks, cracked into significant size blocks and what was happening during wet weather is that these blocks were becoming dislodged by trucks driving through at night and these large chunks of concrete-type materials were left lying on the road and a car following along behind would suffer enormous damage if they hit one. So we had a patrol there, actually working night and day doing what we were calling the divot replacement programme to replace these divots. That caused some problems. The solution to that was to overlay the pavement with asphalt, which was done shortly after that. We put 200mm of asphalt over all the road.' (Hanson, Tape RTA-PRS:FH17, Side B, 37:43)

In the end, the DMR did finally achieve a more satisfying result on another section of the highway:

> 'I'll talk about one area – there's a place they call Frog's Hollow. Every engineer who'd come there, they all said they'd fix it, and they all walked away and they didn't, and they'd patch it and they'd patch it, and they'd dig it up and replace it. They tried stabilising it and it wasn't successful. They'd realised that water was a problem, so they herringboned it. Then they stabilised the whole lot again and then they put the DGB on top, and that was back in the early eighties, and to this day that bit of road hasn't moved.' (Harris, Tape RTA-PRS:FH15, Side A, 15:16)

Stabilisation, which had been growing since the early 1970s fell out of favour in the 1980s. The Princes Highway had reached the end of its 20-year design life and was failing - wet weather caused hundreds of kilometres of its pavement to fall apart and on the Pacific Highway at Port Macquarie, other stabilization failures occurred. Val Brizga is a geotechnical scientist at the RTA's Southern Regional Office:

> 'When we started to do full depth pavements in multi layers we found that they were only lasting a few years before they were starting to crack up and I noticed by investigation that the layers were delaminating and slipping on one another and from that we identified that the bonding wasn't being achieved that we needed and the

> layer thicknesses probably weren't sufficient. We had four or five layers: multiple subbase and base layers.' (Brizga, Tape RTA-PRS:FH25, Side A, 07:37)

The failure of stabilised pavements in the early 1980s, led to a hiatus in stabilisation that lasted to the end of the decade and very little stabilization was done in the interim:

> 'At that stage we were probably limited as to what we could do because the depth of mixing was curtailed by the type of mixing equipment that we had and the maximum depth we could get to was 250mm and that was not adequate enough for deep-lift and if we used 250mm, we always ran the risk of debonding, so those sort of pavements weren't going to last the 20-year design life, and in fact, those pavements were probably going to fail within five years on today's calculations.' (Walter, Tape RTA-PRS:FH1, Side B, 43:31)

In 1989, the Department of Main Roads was absorbed into the RTA and new challenges awaited for stabilized pavements. They were on the brink of entering their most interesting period of development.

The very early days in stabilisation

Older style tractor driven units

Wirtgen specialist mill & stabilise single pass machine in operation, followed by Vibromax 1801 compaction plant

Other binders: slag and fly ash

Doug Prosser is a slag pioneer. His grandparents were Welsh coalminers brought out to work the coalmines in Lithgow in the 1800s. His father started work at 13, stoking a steam crane and became a steam and diesel train driver. The family lived at Cringila, next to the Australian Iron and Steel works where Doug became an apprentice fitter and turner at age 15 in 1939.

As early as 1928, the first blast furnace had been brought into operation by Australian Iron and Steel at Port Kembla:

> 'Interesting in those days, blast furnaces were given a female name and No. 1 Blast Furnace was known as Emily and that was tucked away in a corner of something like 2000 acres of low-lying land and from the moment the blast furnace started, it started to produce slag and that slag was a very valuable resource because it was used to fill those low-lying areas - all those swamps......and that continued until the late sixties, from memory, when they had filled all the low-lying areas and slag was becoming an embarrassment to them.' (Prosser, Tape RTA-PRS:FH26, Side A, 07:17)

There was so much slag produced that it was given away:

> 'In latter years, when Wollongong Council or the Department of Main Roads as it was then were building a road – they were building lots of roads at that time – they would just bench out the road, ring the steelworks and the steelworks would just deliver a metre thick of uncrushed slag material straight from the furnaces, so it'd be steaming and smoking and it made an absolutely ideal subbase. They got it for nothing, or at the most, they paid for cost of cartage.' (Prosser, Tape RTA-PRS:FH26, Side A, 07:18:03)

After some years, Australian Iron and Steel (which had been taken over by BHP in 1935 but still traded under its original name) decided that to give slag away was too good a deal for the users and started to produce its own slag road base:

> 'Slag road base is a very good product, but in those days had to be produced to Specification 744. For a while, they produced a slag with precipitator dust, the so called Red Road Base, and quite a few roads, like parts of Mt Ousley Rd, under construction then used the material. It worked very well until you had a section of road that hadn't been sealed and traffic was allowed on it. Again, no problem until it rained – that's when the problem started. The white cars turned pink and of course, this red road base, extremely fine – it was virtually an ochre – if you had the misfortune of walking on a white carpet, it left red footprints behind.' (Prosser, Tape RTA-PRS:FH26, Side A, 09:10)

After that, Australian Iron and Steel wisely decided to exit the road slag business and in 1970, BMI Industries signed a 10-year contract with BHP to allow them to market their slag product. Doug Prosser then worked for BMI and marketed the slag.

The characteristics of slag for use as a road base were positive. Mal Bilaniwsky is Asset Manager at the RTA's Southern Regional Office in Wollongong:

> 'It had free lime in it and often, it would set up off its own accord, become almost like concrete, and a lot of our roads, particularly with the slag spalls – once you put it down, three or six months later, when you come to do any work with it, you couldn't rip it and you had trouble drilling it.' (Bilaniwsky, Tape RTA-PRS:FH23, Side A, 07:46)

During the 1980s, BHP changed their steel making process and the result was the production of a new form of slag - ground granulated blast furnace slag:

> 'In the nineties in particular, when we were starting designing bound pavements, our first couple of years was with cements, but the biggest drawback was this inability to get confidence in the compaction and get the shape, and if you didn't get it, basically you had only one go at it and you had about two hours to do it – if you didn't get it in those two hours, basically you had a failed pavement – you had to rip it up and start again, so it wasn't considered to be a very effective way of doing things. So what happened in the nineties was - we started to build pavements where we were starting to use slag road bases, but what we did was we actually deliberately put in one to one and a half percent of lime as a catalyst and what we found was that the slag road base, one to one and a half percent lime, would achieve a bound pavement which gave us very high strength, roundabout five Mega Pascals at roundabout eighteen months, but they were slow-setting, that the strength gain would be slow, as we had a lot of time to work and get compaction and get the shape, so we started using slag bases with lime additive, put in through a pugmill on site at the quarry or at 21 Dump, and put them onto our road, so we had a few years to construct pavements in and around Wollongong and the ones that come to mind - work on Mt Ousley Road, Bellambi Creek and the Northern Distributor were all designed this way, and we were starting to get a fair bit of success with that style of pavement around here.' (Bilaniwsky, Tape RTA:PRS:FH23, Side A, 26:35)

> 'Because granulated blast furnace slag, with slag/cement became available, and because it was ground up to such a fine consistency, it meant it was economically viable to use it a long way from the steelworks, and because it had nice, slow setting binder characteristics, it became very attractive to use in road stabilisation instead of ordinary Portland cement, because the working time went from something like two hours to twelve hours plus.' (Youdale, Tape RTA-PRS:FH 32, Side B, 41:34)

Slag aggregate can reduce cement content, making it an attractive, cost effective option:

> 'The benefit mainly is in its cementitious action. That, when you put down the so-called flexible pavement, you're essentially getting a rigid pavement - the benefits of concrete without the price of concrete.' (Prosser, Tape RTA:PRS:FH26, Side B, 37:59)

> 'Next time you drive through the Sydney Harbour Tunnel, just remember that the cement that was used to make the concrete contains 65% ground granulated blast furnace slag, used very deliberately because of the resistance it gave the concrete to salt water intrusion or any aggressive water in the ground. It wouldn't have been used in the Sydney Harbour Tunnel unless it was absolutely spot on.' (Prosser, Tape RTA:PRS:FH26, Side A, 23:18)

The slag dump stockpile was traditionally always named after the Sales Manager of the day:

> 'It's been known as Mt Prosser – that was from 1980 to 2003. There's something like two and a half million tons there. Some six months ago, the company got a bit formal and they decided, looking through their records that Mt Prosser didn't sound very professional and the decision was made to change the name Mt Prosser to '31 Stockpile.' a most unromantic name – so a piece of history has gone.' (Prosser, Tape RTA-PRS:FH26, Side A, 27:03 and Side B, 47:00)

Fly Ash, a by-product from burning coal in power stations is another binder used in pavement stabilisation. The Manager of Cement and Fly Ash at Hyrock, Ron McLaren, has spent most of his life working with it:

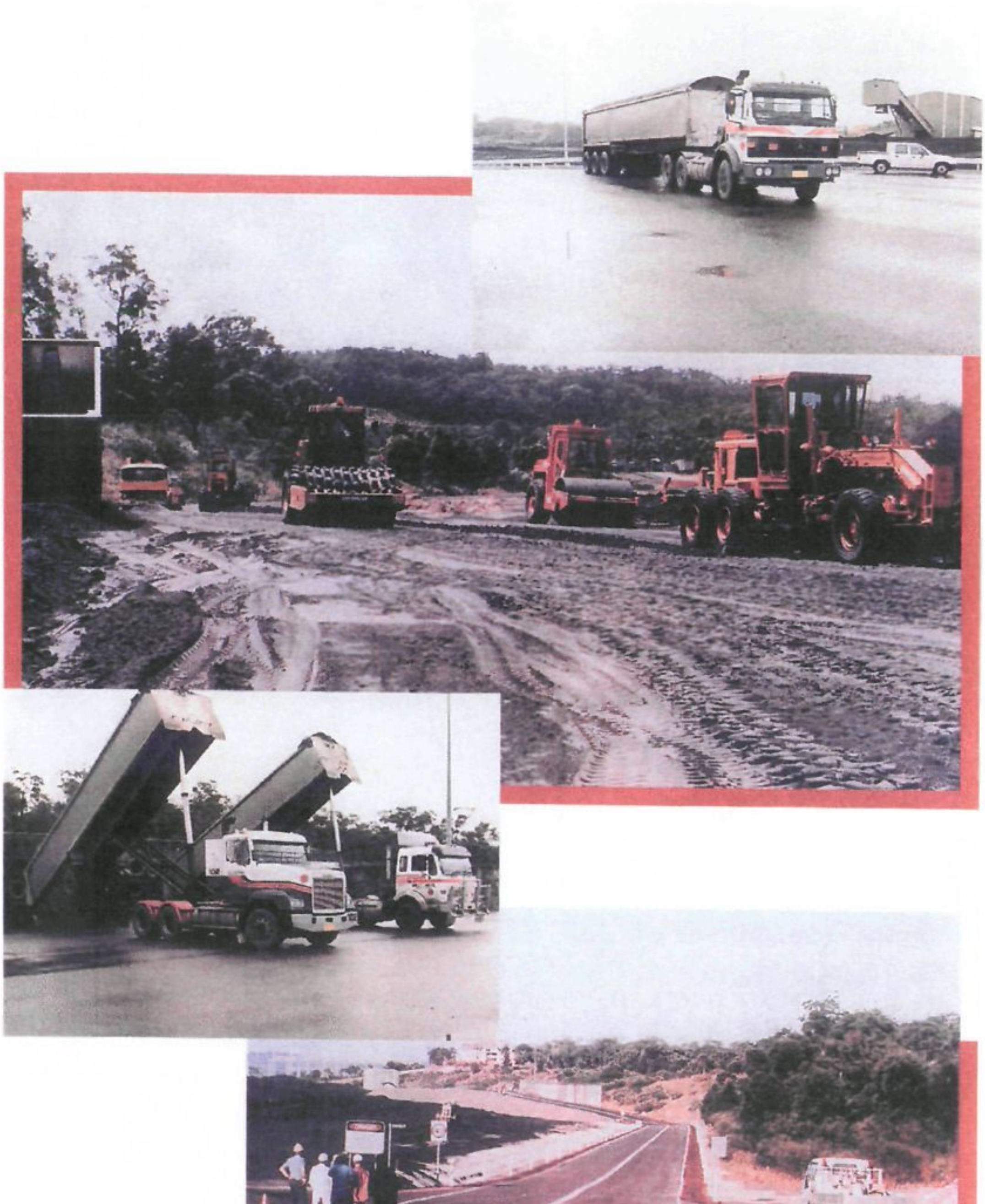
> 'The new generation power stations actually grind coal to a very fine powder - this powder is blown through a boiler, where it is ignited and it's the actual small particles of coal which are basically about 45 microns in size – which is about the width of a human hair, so you're looking at very fine particles - they're carried in an air screen through the boiler. The coal liberates its heat, and in doing so reaches temperatures of about 1100 degrees centigrade. These small particles of coal then fuse into small airborne particles, which are basically silicon alumina, as they're in an airstream, just like a raindrop will form into a little spherical ball, these form into little spheres, which then cool into little hardened particles, which we call Fly Ash. When Fly Ash is used with concrete, it works with the free lime in concrete in a pozzolanic reaction – it binds with it and forms new cements and because the particles are spherical, they actually act as a lubricant. In concrete, we want to put in the minimum water we can, because water in concrete is a real nuisance, so it enables the water content in the concrete to be kept as low as possible and that aids concrete in all sorts of durability aspects, from drying shrinkage, heater hydration and in general, benefits the final concrete.' (McLaren, Tape RTA:PRS:FH12, Side A, 11:39)

> 'Australia, through the stabilisation industry invented Fly Ash cement, and basically what that is, is replacing some of the cement – usually around 25 or 30 percent of the cement with Fly Ash. So Fly Ash-blended cements get the same strength after a period, but the strength develops a little bit slower – well, that helps with stabilisation, because it gives you a little bit of time to work the road before it goes hard. So again, for a lesser cost, you get a product which is actually better – it gets the same strength, but is actually better. So you're doing two things: you're getting a better product… well, three things – you're getting a better product, better cement for stabilisation, it's cheaper and you're using another waste material, so it's environmentally friendly.' (Smith, Tape RTA:PRS:FH3, Side B 47:18)

Greg Johnson is Development Scientist at Rocla:

> 'It's surprising how much strength can actually develop. I remember one of the RTA workers, Val Brizga, down at Wollongong – he had a core in his office from one of the roads that had been stabilised with a lime/Fly Ash blend and he tested the strength of that core. It turned out to be about 30 MPa – now that's quite amazing for a subbase and it's because the reaction just keeps on going on, year after year and the road gets stronger and stronger. The initial strength isn't very high - it may take ten years to get to that kind of strength.' (Johnson, Tape RTA-PRS:FH27, Side A, 15:15)

> 'New South Wales burns about 30 million tons of Fly Ash a year, so a nominal 20% ash content produce about six million tons of ash per year. Total Fly Ash used in all concrete is now approaching a million tons per annum in NSW, or up to 1.2, so in one way, we're only using 20% of it, but the other good news: well, at least 1.2



Full depth fly ash

> million ton is being utilised. The rest is just dumped in landfill – some of it is dumped to rehabilitate old coalmines, which is called void filling and disposed of that way - the remainder is dumped into vast lagoons.' (McLaren, Tape RTA:PRS:FH12, Side A, 20:48 & 21:41)

> 'Binders can be either Portland cement, lime, kiln dust, ground granulated slag – it can be Fly Ash or any combination of those and they're the normal ones that we would look at as inorganic binders, so we use their properties as binders in pavement stabilisation. Then there are other ones which I have some knowledge of, using various bitumen emulsions and bitumens - there's polymers that you can use – there's sodium silicate that you can use, waterglass is being used, and there's combinations of waterglass and calcium chloride, where the Dutch did some work on that in particularly marshy areas, where they basically grouted whole marshes and turned them into something very stable.' (Hinczak, Tape RTA:PRS:FH20, Side B, 42:50)

Ihor Hinczak developed a slow-setting binder when he worked on a problem with testing officer Vic McInnes at the DMR's Grafton office in the mid-1980s:

> 'One of the things that was posed to me by Vic McInnes was that he would like a cement that would work both on granular materials and also would work on clayey materials, so that he didn't have to handle two different products, and being the typical marketing-type person, with some pride, I suppose, I accepted the fact 'Oh yes, we can do that easily' and we went away and that night the sales representative said 'How are you going to do it?' and I said 'I don't know, but I'll have to do it quickly.' By that stage, we were looking at slag and we had a lot of information from overseas, particularly France in the use of slag in road building over there, so we put chemistry and availability to the test and we developed a product which was subsequently named and registered as Stabilment. It caused quite a lot of laughter initially because the managing Director couldn't understand that we weren't aiming the product into horse stables – that we were actually talking about stabilisation and the word was 'stabilisation cement' and we shortened it to Stabilment, s-t-a-b-i-l-ment, rather than s-t-a-b-l-e-ment, so that caused a few laughters at board meetings and things like that. The material was developed in a laboratory – we did some laboratory work by taking local soils and that and adding various quantities to it – we got excellent results – then we trialled some in the Grafton areas with Vic McInnes and this time it was in the Wedding Bell State Forest and it worked pretty well. We did two pavements, side by side: on one side we had Stabilment and on the other side we had a product called Slagment, which was Portland cement with about 35 percent slag in it and they both worked extremely well – the Slagment behaved in a manner similar to Portland cement, so it had some difficulties during the actual stabilisation operations, but the Stabilment went down beautifully and they found that it had a re-work period of about 3-4 days, which meant that if there was any disruption to the pavement, or any rutting or that, they could re-work it without losing strength and if you keep re-mixing it and re-blending it, it would work well. This was in fact tested to its extreme in a job in 1987, just outside of Lithgow in an area called Forty Bends, where they used Stabilment in the reconstruction of the Great Western Highway, and the RTA, or the DMR as it was still known in those days chose a period of time to do that when the weather was good, so they thought they wouldn't have too much disruption to the traffic, but I think Murphy must have been employed at that period, because they got a lot of rain and every time they stabilised a section it would rain – they had to let traffic over it – it would rut and what they found is that they didn't have to cut and redo the pavement – they could in fact re-work it, and they did that a number of times... they were a little bit

> concerned, but when they did finally put the seal on in the period when they were able to and they found there was no distress in the pavement at all.' (Hinczak, Tape RTA:PRS:FH20, Side A, 28:12 & Side B, 34:37)

In the early 1990s, Greg Johnson and Rocla salesman Harold Driscoll invented a new blend of binder:

> 'Harold was the sales guy up there in the field and I was doing development work back in the lab. Harold was certainly an excellent salesman. What he always said back in those days was that we needed some means of differentiating our blends from the opposition blends. Now there was one thing we could do that they couldn't do – we had the facilities to blend more than two components – we had enough silo capacity to blend three or even four materials together – the opposition companies only had two silos, so they could only do double blends. So Harold came up with the idea of selling a Triple Blend and so we started doing that, and Harold went along to a conference – I think it was an RTA conference - and started promoting the idea of Triple Blends and somehow the RTA picked up on this idea and all of a sudden, specifications started to appear where they actually said 'You will use Triple Blend.' So the contractors would come to Harold and say 'We want this Triple Blend.' Harold would come back to me and say 'Look, they've asked for Triple Blend' and I would say 'Well, which particular variety of Triple Blend are you talking about here – are we talking cement/Fly Ash/lime or lime/Fly Ash/slag, you know, there's a whole range of them, so what we finished up having to do was ask the contractor to supply a sample of the soil and we'd have a look at it and decide from the makeup of that soil which particular Triple Blend would actually be suitable. At the time, we thought it was a bit of a gimmick, but there were some soils that did seem to respond to the Triple Blends, so it developed into something that did have some scientific backing to it.' (Johnson, Tape RTA-PRS:FH27, Side A, 18:29)

Other forms of stabilisation

In the 1960s, the DMR had conducted a lot of field trials with different ways of stabilising pavements. Some of these were with foamed bitumen stabilisation:

> 'I was involved personally in some foamed bitumen research work that we did in the laboratory. We actually built a machine that could produce foamed bitumen in the laboratory and did some trials. There was a trial carried out on Elizabeth Drive, west of Sydney.' (Youdale, Tape RTA-PRS:FH32, Side A, 19:50)

Ron Hocking is one of Australia's foamed bitumen pioneers.

> 'When originally, when we first set it up, we set it up with a steam generator, which is a super-heated steam, it had to be and it had to be a certain moisture content coming out, so there had to be adjustments made. It was only a little five horsepower motor running it as a pump, but it really pumped out some steam. It was a lot of mucking around and a lot of attention to keep it working... you had to be at the nozzles all the time to make sure that they were foaming consistently well. You had to be very careful all the time of splashbacks, because you had very hot hoses running all the way around the machine going backwards towards the bitumen tankers. I got a couple of burns at different times, where I got a splash of bitumen, but not much.' (Hocking, Tape RTA-PRS:FH9, Side A, 26:59)

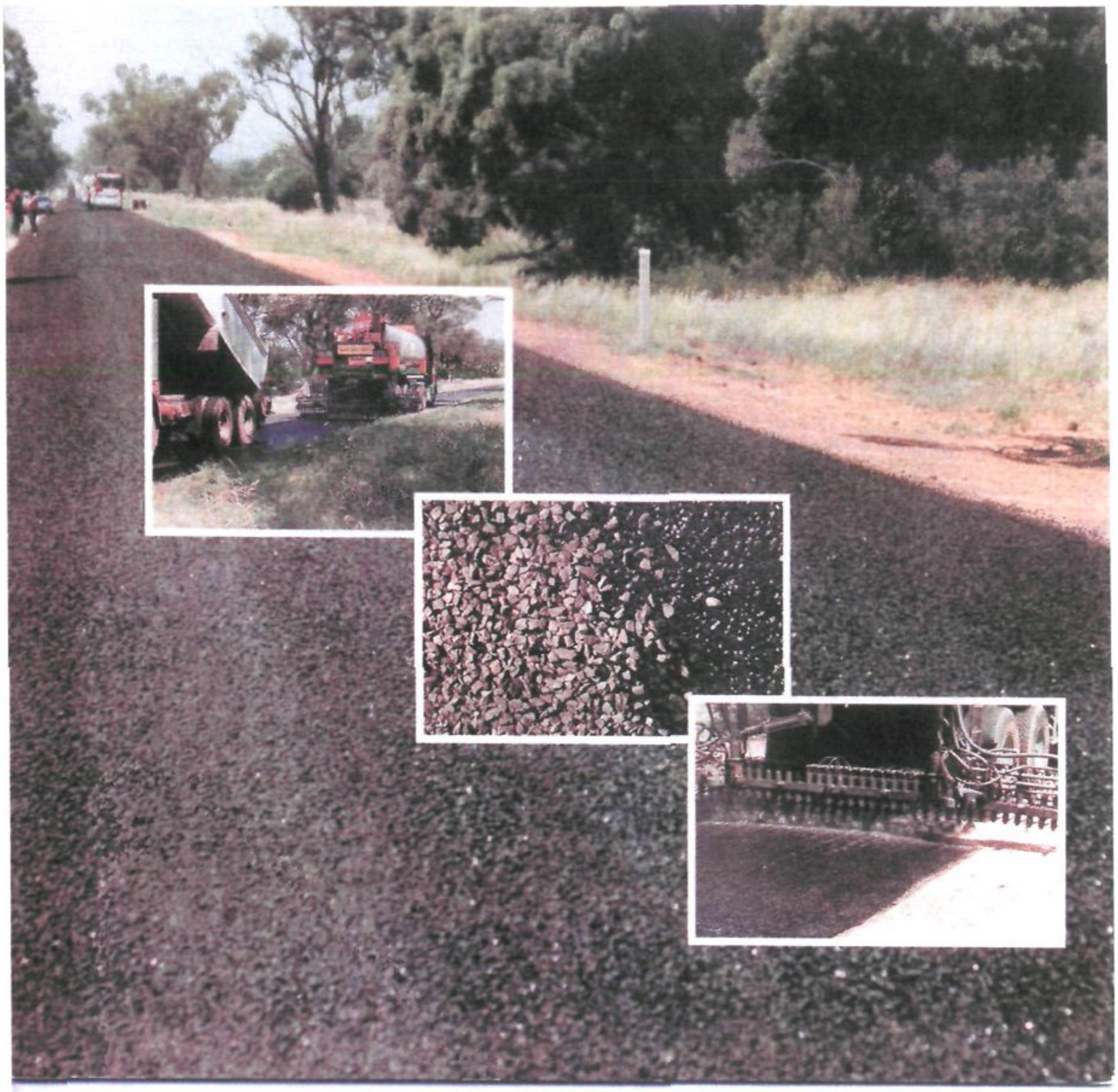
> 'Any hydrocarbon, whether it be cooking oil, making a pappadam or your chips or hot bitumen: if you add a little bit of water to it, a very small percentage, you get a violent expansion. In the bitumen industry that used to be very fatal- it would cause mayhem and possibly kill people.' (Smith, Tape RTA-PRS:FH3, Side B, 58:09)

Tom Wilmot also worked with foamed bitumen in the 1970s:

> 'We worked with what would now be considered very dangerous, antiquated equipment, but the work was very successful. We stabilised the shoulders of the runways at Tullamarine, which, as far as I know are still standing in that same condition, we did some work at Walgett and although that was not so successful, it was because we were using, as a request by the Main Roads, lower than recommended bitumen percentages – the section we did with the correct percentage behaved very well and lasted quite a long time. We had a rather funny experience there – halfway through the project we had very heavy rains and we had the traffic on the side track and barricades across the road to stop the traffic using the newly constructed road, but the locals decided it was too wet to go on the side track, so they removed the barriers and went on the road, so the next day we dug a trench across the road so that they couldn't get down the road and had to use the side track. The next morning we came out and they had used the barriers to create a bridge across the trench so as they could get back onto the road. We gave up after that.' (Wilmot, Tape RTA-PRS:FH18, Side A, 14:23)

Brian Shackel, now a professor at the University of NSW tested foamed bitumen in the 1970s for Mobil Oil, which owned the patents to the process, with inconclusive results:

> 'The foamed stabilisation – we made up samples of material and we tested them, using repeated triaxial loading, which in those days was quite an exotic test and there



Foamed bitumen

> weren't many laboratories capable of doing that. Shortly after we did this work, there were some successful applications of foamed stabilisation – for example at Sydney airport. However, most of the work we did showed that the strength and the stiffness of the materials that we tested were not improved by foamed stabilisation. Almost all of the materials we tested, in fact - their properties were better before we put the bitumen in than after.' (Shackel, Tape RTA-PRS:FH38, Side A, 27:50)

Foamed bitumen stabilisation fell out of favour when oil and bitumen prices increased in the 1970s. It made somewhat of a recovery in the 1990s, when the patents expired, and by then new techniques using water rather than steam were available:

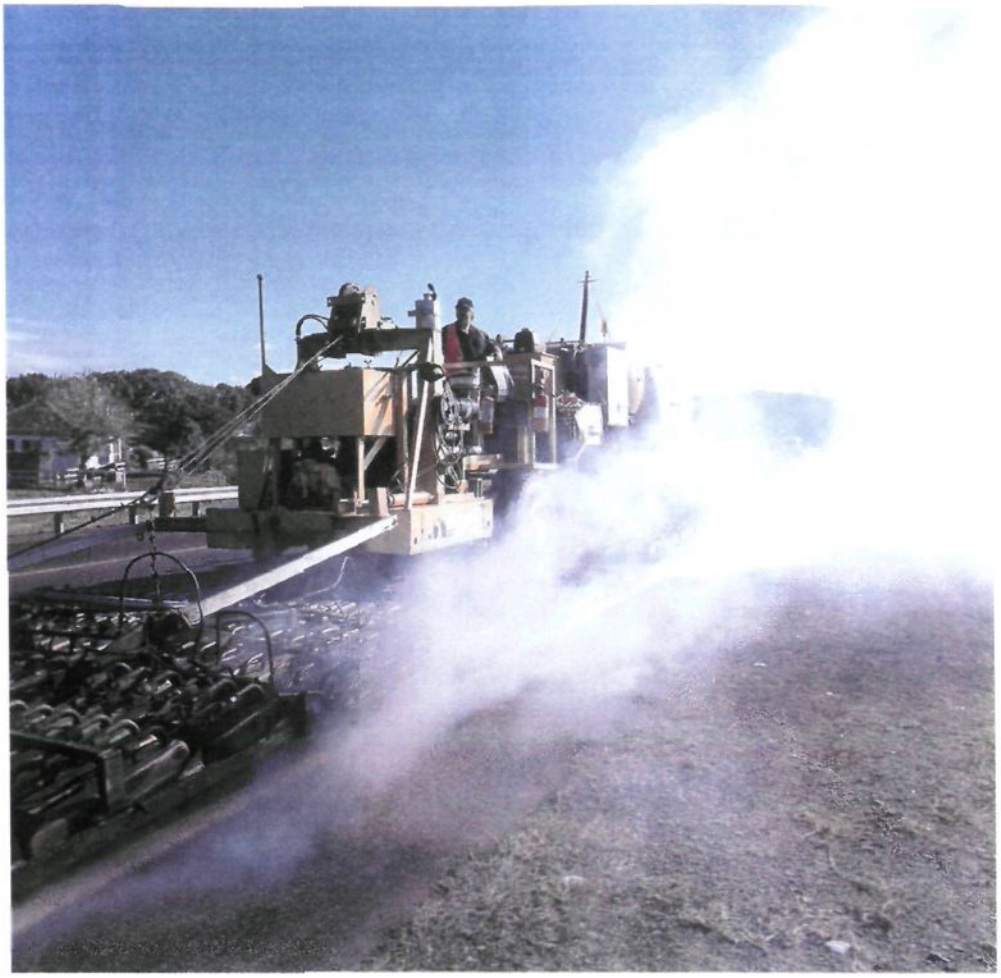
> 'They've created a methodology whereby you can deliver bitumen to the bowl of a stabilisation machine, adding a minor amount of water. You can foamed that bitumen and mix it more effectively than you used to be able to and more uniformly. Unfortunately, it's very expensive – bitumen is much more expensive than cement.' (Porter, Tape RTA-PRS:FH6. Side B, 37:22)

Bitumen emulsion is a different method to foamed bitumen stabilisation.

> 'Bitumen emulsion has been widely used through Australia, both in plant mix and in insitu processes. One of the challenges with emulsion is that it becomes expensive, because it's a water and bitumen product and with our vast distances, you end up having to cart both bitumen and water to sites, so therefore the cartage cost impacts on the price of the process. The other thing is some of our materials are already wet and adding more water to a process means that it becomes too wet for compaction and ability to open to traffic, so today, I'd say that the bitumen emulsion type process is becoming out of favour because we're looking at cheaper solutions, such as foamed bitumen.' (Vorobieff, Tape RTA-PRS:FH22, Side B, 30:18)

HIPAR, Hot in Place Asphalt Recycling is yet another form of pavement stabilisation:

> 'Hot in Place Asphalt Recycling is where you use gas burners pushed in front of a profiling-type machine and material is added – it can be either emulsion or even hot mix. It hasn't been widely used, it's reasonably expensive - it is used to some extent in Europe, but only on a small percentage of the network and it has been used for trial sections with varying degrees of success in NSW. We will keep using it to have the technique available, but it's unlikely to be a widespread usage. It's generally going to be a fairly substantial pavement already you're going to treat in this fashion and in may cases, just milling the material off, taking it and adding it to a recycled asphalt pavement is a more economical treatment.' (Dash, Tape RTA-PRS:FH 30, Side B, 13:35)



Hot in Place Asphalt Recycling

Hot in Place Asphalt Recycling – gas pavement heaters in use

Hot in Place Asphalt Recycling

Upside down pavements

The winter of 1981 was a wet one in Southern New South Wales. It took its toll on the Hume Highway and sections were failing spectacularly. Ray Gerke and Geoff Youdale inspected the Highway and proposed a new strategy for strengthening the road:

> 'That's where this concept of the upside down pavement developed, which basically involved putting a stabilised layer deep down in the pavement and the unstabilised crushed rock at the surface, which is more flexible. Ordinarily in pavements, you put your strongest material at the top and as you get deeper down, then you get weaker material, but the upside down pavement will actually have the stronger material down in the pavement. The advantage with this pavement design is that the stiffer, cemented up layer in the subbase actually reduced deflections quite significantly and that allowed the crushed rock base layer at the top to perform better under traffic loadings.' (Hanson, Tape RTA-PRS:FH17, Side A, 17:50)

But upside down pavements soon presented a new challenge:

> 'They thought the reflection cracks from the subbase would be stopped by the granular layer on top. That was the theory, and these sort of pavements worked out quite cheaply because you were putting the stabilised layer at the bottom, which meant that the tensile strain on that material was a lot lower – had a lower level. So these formed fairly cheap pavements, but they suffered from what we found later on was impermeability reversals. As water got down through the seal and through the granular base material, it would strike that impermeable subbase layer and the water had nowhere to go but to wet up the material above, and so we had failures in the base materials.' (Walter, Tape RTA-PRS:FH1, Side A, 21:42)

Val Brizga also has his doubts about upside down pavements:

> 'When I first came to Wollongong, they were constructing an upside down pavement for the Kiama Bypass which I knew immediately would be a bad pavement design and would immediately fail. And it failed quite soon, due to permeability reversals. An upside down pavement comes out very good on paper, but in practice – once you have fatigue cracking or something at the surface, the base is quickly saturated and quickly fails under continued loading. It was a fad at the time.' (Brizga, Tape RTA-PRS:FH25, Side A, 15:55 & 17:52)

In time, it was discovered that for an upside down pavement to be successful, it had to satisfy an important condition:

> 'We are still building upside down pavements, but what we are looking for today is for a material as the base layer which is moisture insensitive and there are a few gravels around which are moisture insensitive. That means that when the material wets up, it doesn't lose its strength dramatically. And so those pavements are still very cheap and economical to produce and perform very well, but the secret is to get that moisture insensitive base material on top.' (Walter, Tape RTA-PRS:FH1, Side A, 21:42)

Brian Hanson still champions the upside down pavements:

> 'They were very successful at Holbrook, on the Hume Highway, perhaps because ordinarily the rainfall is not as high as some areas. Pavements we built back in the 80s are still performing today quite well.' (Hanson, Tape RTA-PRS:FH17, Side A, 20:10)

Why aren't more upside down pavements being built today? Geoff Youdale has the last word:

> 'Because generally the traffic is very damaging these days – axle loads have gone up, truck sizes have gone up, in particular tyre pressures have gone up quite a bit and they're looking for a longer life. You're looking for a concrete pavement or a composite pavement where you might have lean mix concrete or heavily bound stabilised material with deep strength asphalt - maybe 170mm to 180mm of asphalt. They require less long term maintenance than having the unbound granular layer in the middle of an upside down pavement, which is susceptible: if you get water into it, it will fail.' (Youdale, Tape RTA-PRS:FH32, Side B, 57:27)

What lies beneath: investigation and preparation

The stabilisation process always begins with investigation. It is the most important part of any contract:

> 'One of the problems with stabilisation is that it relies on existing materials, so you're limited to producing a product which is dependent on the existing material – you don't always know what that material is in every part of the roadway. So you need some tolerance and cement stabilisation and most other products provide some tolerance to this. But engineers, more and more are asking for a higher performance out of their roadways - much more frequent loading and becoming tighter in their specification requirements. One of the concerns about stabilisation is that people make it to expect too much from what is a relatively basic process and one of our challenges is to ensure that stabilisation will do that.' (Wilmot, Tape RTA-PRS:FH18, Side B, 54:37)

> 'There's always been concerns about the process and one of the risks associated with that, is that at times when we try to investigate what type of materials we're working with and how deep those materials are, when we go out and build these roads there's something different. Many engineers would scratch their head on site and say 'we never anticipated this.' In fact, some contractors will tell you sometimes farmers used to bury car bodies in rural roads and out when you're on site and you all of a sudden experience something different or a pipe across the road, so these unanticipated events will cause problems with the pavement performing.' (Vorobieff, Tape RTA-PRS:FH22, Side A, 22:44)

> 'The largest debate in stabilisation is the degree of investigation you carry out. We now have guidelines, actually for stabilisation – we want deflection readings over the full length, we want investigation pits every 250 metres in the main and we want sensitivity testing of the various binders, so they're all designed to see the existing conditions, the uniformity, because invariably, subgrades are non-uniform and it's more economic to isolate the poor sections and treat them differently, rather than doing expensive treatment over the full length. Investigation is not always seen as a necessary criteria or initial step – it's a cost. It may be 3% of a project cost. The other costs are fixed to a certain degree and competition in contract work … you're looking at the variable cost and if you can reduce the variable cost you can win a contract. The number and equipment laboratories have is reducing and that is a problem in Quality Assurance, which is seen as contractors carrying out their own investigations and Quality Control and again, that's a variable cost that is minimised in many cases.' (Dash, Tape RTA-PRS:FH30, Side A, 26:33 & Side B, 27:59)

Allan O'Meara is a grader operator and Supervisor in deep-lift Stabilisation. He has driven every kind of stabilisation machine made. What are the consequences for an operator if the road has not been properly investigated?

> 'The machines just collapsed and the machines just bogged. You've actually got to pull the machines out if it hasn't been investigated properly, because once you break that surface and you're in the clay area, people don't know it, driving in a car, or we don't know it if it hasn't been investigated. Because once you break the 200 and you hit a

> wet area of clay – yes you'll get bogged. (O'Meara, Tape RTA-PRS:FH13, Side A, 16:51)
>
> 'Last week I hit a water main, I lost a million litres of water every 15 minutes – that went for four hours, so I lost 20 million litres of water last week. I'm responsible for it, because I did it. I didn't know it was there, due to the ground search, it wasn't marked out for me, but it still comes down to me. I did it. And I had all my 'dial before your dig' but that's immaterial. And also the pressure - when it did break, it lifted the road up in the air. It left a hole of 10 metres deep in the road. (O'Meara, Tape RTA-PRS:FH14, Side A, 03:59)

O'Meara survived that experience because, despite the mishap, he is still in great demand.

Design methods

Pavement design methods have undergone a major change since the days of the old system of Empirical Design developed by Sandy Britton in 1948 and used until the late 1960s. Britton, the first Research & Materials Engineer was a highly intelligent person skilled in mathematics, according to Phil Walter:

> 'The Empirical Method was based on almost just a rule of thumb where values were assigned to things like grading, moisture relationships and by applying those factors they just came up with a sum at the end, which gave you a thickness of cover over the sub-grade.' (Walter, Tape RTA-PRS:FH1, Side A, 16:27)

Alan Leask, then in charge of the Materials and Research Laboratory introduced the Mechanistic design method to the DMR in the 1970s:

> 'During the 1970s, late sixties and 1970s, people started to look at the elastic modulus of pavement materials and analysing layers and foundations for buildings and silos, as well as roads, on the basis of the elastic properties, and we call this a mechanistic approach, whereby you can have a pavement material with a particular modulus and behaviour that you can define and another pavement material that has got an entirely different grading, perhaps a different plasticity, but happens to have the same strength properties for a number of different physical reasons and will perform equivalently. This meant that your selection of gravels and the nature of materials that you build your pavements from could expand, because you'd understand the mechanistic behaviour a lot better. And so we started to relate our empirical pavement design to mechanistic properties and therefore we could accelerate the development of mechanistic design. So there was a major acceleration – particularly in Australia, using a software programme called 'CIRCLY' which was an Australian product, Australian developed software for the linear elastic analysis of pavements in multi layers and it was that research and that move to mechanistic design that enabled us, for instance, to consider a stabilised layer and say – well for 300mm of stabilised layer we could replace 600 mm of granular material, and with 300mm of stabilised layer, if we did the analysis, we might be able to replace the 180mm of asphalt. And so then we've now got a choice, and we can look at the supply of local materials, the costs, the construction method, the traffic and then decide how to build a pavement. So it opened up a lot of horizons for us. The unfortunate thing at the time was, we didn't think we had the equipment to put down – say 300mm. So that's what mechanistic design meant in stabilisation and how it developed.' (Porter, Tape RTA-PRS:FH5, Side B, 33:06)

Mechanistic design methods were accepted by the DMR and RTA and are now in common use throughout Australia.

The Aran Pugmill

Stabilisation can be done in two ways: plant mix and insitu. Plant stabilisation uses pugmills, a conveyor belt mechanism that feeds material from a stockpile up into a rotating shaft with paddles (or 'mill'):

> 'It has chutes and weighing controls from other conveyor belts.... Pugmills were set up in some quarries, where they would actually add stabilising agents to quarry product. There was prime, new product and on some occasions they had mobile pugmills that they could deliver to a site for a period of construction and could stabilise there. One of the brands of these was Aran, which was a modern brand, which perhaps was more mobile than the other brands, lighter, easier to use, better production, and so one milestone, I suppose is pugmill development and crushing material and the movement of stabilisation from the subgrade of the pavement up into the base layers and the subbase layers.' (Porter, Tape RTA-PRS:FH5, Side A, 24:01 and Tape RTA-PRS:FH6, Side A, 19:16)

Trevor Dunstan designed and built the Aran Pugmill, which became a standard for the industry. It all began when Hartwig Schroeder of Farley and Lewis wanted a mobile pugmill for a cement stabilisation project near Townsville:

> 'And so I sat down on the dining room table at night with a calculator and a pencil and nutted out what this thing was going to look like, and how it could all be packaged on one trailer, and where we'd put the mixer and the metering and feeding system and the silo, and I came up with a design of a plant which had an integral feed hopper, its own engine, a mixer, discharge conveyor and a self-elevating silo, and I worked out all the dimensions and made a quote to these folks and it would never happen today, but Herr Schroeder bought this thing over the telephone.' (Dunstan, Tape RTA-PRS:FH11, Side A, 09:18)

Dunstan and his partner were given just eleven weeks to design and build the pugmill, which they achieved. It soon proved itself and the road authorities were very supportive of the new machine, as they allowed materials to be used on small job sites and the quality of mix was superior:

> 'Those plants were principally mobile plants- they were self contained in one unit and they were primarily designed to add a binder at a modest dose rate – at the sub 10% range. Some of the later ones had capacity for two and even three primary ingredients, where it might be necessary to adjust the grading by adding some sand, or something like that. At the rear of the machine was one hopper, or in the later machines there were two, that were loaded from either side, below which was the metering feeder, which was a belt feeder.' (Dunstan, Tape RTA-PRS:FH11, Side B, 30:02)

What made the Aran pugmill different from the others?:

> 'The thing that our machines did that they had not had before was that they were able to give a measure of quality control. Previous to that, there had been very little success with good binder metering and our binder metering system was able to produce consistency that just hadn't been achieved before and it did allow those types of pavements to be used with a greater degree of predictability. We were the

> first people, probably anywhere in the world, to be able to meter cement on a continuous basis very accurately and we still hold our heads high in being the technology leaders in that field.' (Dunstan, Tape RTA-PRS:FH11, Side B, 40:25 & 50:25).

After the machine had been in use, Dunstan made further modifications to the configuration of mixing blades and then came up with a design for a cleated belt feeder, his contribution to continuous mixing technology worldwide:

> 'It was an amazing improvement over anything that had been there before and we were able to meter cement and Fly Ash very accurately with very good repeatability and excellent standard deviations, which hadn't been previously possible.' (Dunstan, Tape RTA-PRS:FH11, Side A, 23:25)

Australia still has 40 or 50 Aran pugmills, but with the decline in the pugmill method of construction, a number have been shipped overseas, mainly to Asia. Dunstan feels that with the Aran Pugmill, he made a significant contribution to stabilisation:

> 'We made it possible. The mixing machines of the day were a lot worse than they are today. There are a lot of other things we made possible as a consequence to that – we've been one of the leading players in making dam construction more affordable. That is a direct result of our involvement in stabilisation and there are people in many parts of the world now that have water that they otherwise wouldn't have been able to afford, because of that, and there are people who have had their environment cleaned up because of that.' (Dunstan, Tape RTA-PRS:FH11, Side B, 56:56)

The birth of deep-lift insitu stabilisation and the R&D Trials

The development of equipment used in stabilisation was largely uneventful until the beginning of the 1990s when large, new machinery for insitu stabilisation first became available after a series of full-scale trials across New South Wales had been held.

At first, there were the trusty old P&H, Bros and Raygo/Caterpillar machines. The P&H machines with three rotors that the Americans had left behind were favoured by many for clay materials:

> 'We believed strongly in the P&H with its triple rotor. Then the Americans developed machines marketed as Raygo or Caterpillar, which were a single rotor machine – they were more powerful, they were more modern – they could dig a lot deeper than the previous machines, and they were rubber tyred, rather than track mounted. We developed a process of mixing at least twice, often three times with these machines to get a mix similar to that produced with the P&H machine. The big development after that was when the RTA moved into what we now know as deep-lift Stabilisation. About that time, CMI produced a much more powerful machine known as the RS-500. The principle of the machine was exactly the same as these other machines – it had a centrally mounted mixing box and it had a lot more power, a lot more ability to cut and to reclaim.' (Wilmot, Tape RTA-PRS:FH18, Side B, 44:38).

For the trials, the contractors wanted to use Bros and Caterpillar machines, as well as an early Wirtgen machine. They also depended heavily on vibrating pad foot compactors. After the trials, the contractors had shown it could be done, but they went looking for bigger, more powerful recycler machines and the CMI machines were an early and successful choice.

The CMI machines were marketed by a rather flamboyant character:

> 'We had a visit from a Texan who was selling the CMI machines – he was the real Texan in all sense of the word, with the cowboy boots, the cowboy hat and the string tie and he had a video that showed comparison of the CSI machine virtually to every other machine on the market. We were impressed with the size and power of this thing – it was really much greater than anything that we had on the market, so the knowledge of that became an opportunity to perhaps try and twist industry's arm to become interested in getting one of these into Australia.' (Youdale, Tape RTA-PRS:FH32, Side B, 37:42)

There was one problem, however: the new machines cost over three hundred and fifty thousand dollars. It was Tom Wilmot who took the risk:

> 'I actually went over to CMI in the States to investigate this machine before we bought it. We ran some trials over there in Oklahoma City .... some points I wasn't happy with and we did some quite significant alterations to the first RS-500, which was done in the factory over there, and most of those modifications were incorporated in future RS-500s that CMI produced.' (Wilmot, Tape RTA-PRS:FH18, Side B, 51:41)

It soon became evident that the new machines were a major step forward – some would say a milestone – in stabilisation because they could go deeper than had ever been possible before:

> 'These machines were really exciting, they were 500 horsepower of American grunt and they were beautiful to watch - they could work in both directions and they could literally eat the road and mix it – and the quality of the mix was so far superior to what we'd seen previously.' (Porter, Tape RTA-PRS:FH6, Side A, 10:01)

The new machine held the promise of being able to recycle entire existing pavements:

> 'The concept behind deep-lift was to stabilise full depth pavement, which would be the base and subbase, all in one layer – when we talk about base and subbase, the material quality is much the same from top to the bottom. The concept behind it was to produce a single thickness of material which had no problem with interface layers between base and subbase – the layer was stabilised, the binder was added and mixed in a single layer and a single layer was compacted, using heavy rollers.' (Walter, Tape RTA-PRS:FH1, Side B, 41:23)

> 'The RTA came up with a design requirement that if stabilisation was to be used on major highways, they would require a depth of at least 350 millimetres. The RS-500 met the mixing requirements. We also developed spreaders, which were a lot more accurate and had on board weigh scales and computer read-outs.' (Wilmot, Tape RTA-PRS:FH18, Side B, 48:04)

If the pavement types identified by mechanistic design were to be put to reclaiming the roads of New South Wales, using insitu materials and insitu methods of construction, the RTA decided, if needed, to put both machine and materials to the test in a series of full-scale trials:

> 'We got the binder suppliers, the contractors who did the work, the equipment suppliers and the pavement designers together in a workshop and we said 'This is what we think we want - what can we do to achieve it?' That workshop brought up a number of issues. As a result of those issues, we decided to fund some field trials under the R & D program, we appointed Ken Porter to be an intermediary to help organise these and over the next couple of years we funded these field trials and I guess the major issue that we funded was the attempt to extend and develop deep-lift Recycling techniques for main roads standards and state highways within New South Wales.' (Youdale, Tape RTA-PRS:FH32, Side A, 28:43 & 25:40)

There was some initial scepticism, especially from the other States about whether the trials would achieve their objectives:

> 'It wasn't only in the other States, but there were people in New South Wales who did not believe in the trials as well, because in their experience, they had used normal cements and they had used thinner layers – they'd developed cracking and they couldn't believe that we could do it without developing cracking, or at least minimising the cracking.' (Porter, Tape RTA-PRS:FH5, Side B, 53:18)

It was a unique opportunity to put theory to the test:

> 'It was a new idea at the time and had to be proven, so theoretically it was fine, but as we were embarking on it, we also realised at the time: 'Hang on, this is a new process: theoretically it should work.' The areas I had concern about was that we

> were using natural gravel, where we had a lot of history of quarry products up in the Wollongong area, and using the slag pavements, process controlled through the pugmill, through the quarries themselves and brought on site in a controlled manner – here, we were using natural materials, insitu, on the ground, variable quality, variable, thicknesses, often lack of subgrade support and different variable moistures, so we had to learn a lot of things very quickly.' (Bilaniwsky, Tape RTA-PRS:FH23, Side B, 35:09)

The R&D Trials in deep-lift stabilisation were held at Nimmitabel, Narrandera, Parkes and Dubbo:

> 'We decided to run a number of these trials, primarily because they were in different districts with different materials. We wanted to try different binders and we wanted to be fair to the contracting industry, so we funded these trials over a two-year period. They looked at a number of different binders and a number of different soil types. It was largely an equity issue and to see if we could operate in different conditions and be fair to the industry and that seemed to be well appreciated by the industry.' (Youdale, Tape RTA-PRS:FH32, Side B, 46:15)

> 'We were, in the first instance working on pavements that were probably only 250 mm thick and we wanted to deep-lift stabilise 300mm to 350mm, and we did some laboratory trials, as you would do, and decided that we were going to pull some of the subgrade up into the mixture in order to achieve the 300mm, and in some cases that was a fairly heavy clay material. So we needed a stabilising agent that would work with that clay and with the gravel and would give us setting time that would enable us to fully work the material, compact it and trim it. In other instances we were spreading some quarry product, 40 or 50 millimetres of quarry product on top of the road to give us the thickness of 300 or 350 millimetres, because we didn't want to mix with the clay subgrade, because it was a problem. So they were heady days and suffice to say, we had some successes, and we were achieving outputs in the order of – even in those trials – of 1,000 to 1,200 square metres of production per day, 300 millimetres thick, and achieving a very compact, very hard pavement which could then be trimmed and sealed.' (Porter, Tape RTA-PRS:FH5, Side B, 42:17)

Achieving compaction was a hot issue during the trials:

> 'You would normally choose, if you didn't have a time limit, and you weren't trying to build one layer, to compact these materials in 150mm to 200mm depths at reasonably optimal moisture content. To compact these layers - we wanted to get compaction right through from the bottom to the top – we were willing to accept only a minor amount of gradation, so that if the compaction at the top was 105 percentage points of the maximum compaction, we wanted the compaction at the bottom to be, say, 101 or 102 percent – we didn't want a steep gradient across the depth of the layer. To do that, we needed time, so we had to get on there quickly with the rolling gear that we used, and to do that, we needed the heaviest equipment we could get that really bashed the pavement with a good reaction load. To do this, we also needed that reaction load to be dynamic, so we needed vibrating rollers. You can imagine a 300mm layer, if we used what was the conventional smooth drum vibrating roller at the time - as it densified the top of the layer, which it has its first and primary impact on, that would in fact mask its ability to compact the bottom of the layer. To get over this, we used an old construction technique of using pad foot rollers or sheep's foot rollers. We used both and found that a modern pad foot roller was the best method and the best approach to the problems that we had. We had to give them about eight or nine passes of an 18-tonne deadweight, vibrating at

Stabilisation on the Hume Freeway in the 1980s

View of ALF machine at Cooma adjacent to the Monaro Highway

> maximum amplitude, so that the pads compacted the bottom and the roller rode out of the layer, so it compacted it from the bottom up, and then we achieved the density gradients that we were looking for in most cases under controlled circumstances.' (Porter, Tape RTA-PRS:FH5, Side B, 48:17)

In hindsight, how successful were the trials?

> 'The experience from those trials provided the guidelines as how to carry out the future work and I guess the lessons we learnt from those is that we should be going for heavily-bound pavements, because the lightly bound trial did not last very long. We learnt quite a lot about process control and there was a lot learnt about improvements in spreading, improvements in mixing.' (Wilmot, Tape RTA-PRS:FH19, Side A, 02:12).

> 'What happened after the R&D trials was that this process took off – there was quite a bit of it done – and we became a little bit concerned that while this was a good process, we hadn't had any experience with the long term performance, particularly in terms of shrinkage cracking of cemented materials, which always occurs. As a result of that, an ALF Trial was developed, that was run at a site near Cooma, and that was run in 1994, so that we could assess, or try to assess the long term performance under heavily trafficked loads of these materials.' (Youdale, Tape RTA-PRS:FH32, Side B, 51:15)

> 'An ALF accelerated loading facility is a large frame, where a half axle dual tyre can run across a pavement rapidly and we can produce that sort of 20-year life in a few months and so it's also placed on top of the pavement as constructed, so you can construct a pavement by normal means and normal exposure situations and we did that in a quarry adjacent to Monaro Highway, near Numeralla River, 20 kilometres north of Cooma, and then tested it to show that in actual fact this pavement would perform for 20 years in those support drainage kind of situations. The only limitation we set was – we weren't testing the long term environmental, which was the shrinkage cracking situation, because obviously we tested within a few months, not over the life of the pavement, but it was shown that we could confidently go ahead and continue that type of work and we would get reasonable life from it.' (Dash, Tape RTA-PRS:FH30, Side B, 47:41)

At the end of the trials, the RTA held another workshop to present the results to the participants:

> 'It was held to present comments and difficulties and to also present the Draft Guidelines on how to do this, and the Draft Specification for comment. There was disagreement about some aspect of the guidelines – for instance, we insisted in the guidelines that when mixing the binder with the gravel that two passes of the reclaimer be used to ensure that we get a very uniform mix. Some people involved, particularly in the industry, said one pass was enough. We thought this process generally achieves about 40% cost saving in rehabilitation of existing rural roads and we thought if we were achieving 40%, why achieve 45% and take a big risk, so that's still been a bit of a bone of contention, but it's still in the specification that you need two passes.' (Youdale, Tape RTA-PRS:FH32, Side B, 49:08)

Deep-lift insitu stabilisation increased production rates phenomenally:

> 'It was very, very quick. We started to knock over a kilometre of pavement rehab per week, using deep-lift Insitu Stabilisation processes. We knocked over a very poor section known as Billilingra Straight, which is just north of the Numeralla Trial – it was a four kilometre straight with approaches – we knocked over nine kilometres in less than three months, and had we used quarry based products to do a granular overlay, it would take us four to five weeks to do a kilometre, versus a week a kilometre.' (Bilaniwsky, Tape RTA-PRS:FH23, Side B, 49:40)

> 'We're doing more square metres a day – our production is up. In the old days, I think if we done a thousand square metres, like, the company would take us out for tea. Now they're expecting 5,000, 6,000 a day and that's a normal day's work!' (O'Meara, Tape RTA-PRS:FH13, Side B, 41:12)

However, recycling a pavement to a depth of 350mm can have a negative effect on the machine:

> 'They're very high maintenance machines – they're, what you might term self-destructive. You have these small picks, rapidly impacting the ground and there's a lot of damage, both at the rotor and through the whole drive train. We've had some projects where we've ruined more than the teeth – we've ruined the whole mixing box and that maybe meant parking the machine for a couple of days for a total repair. We had one in Indonesia only last week where we destroyed the entire mixing box in one day, almost. In terms of New South Wales work, it usually comes from striking heavy stone, but the greatest problem is floating rocks and a large rock going through the mixing box can cause a lot of trouble.' (Wilmot, Tape RTA-PRS:FH19, Side A, 05:52)

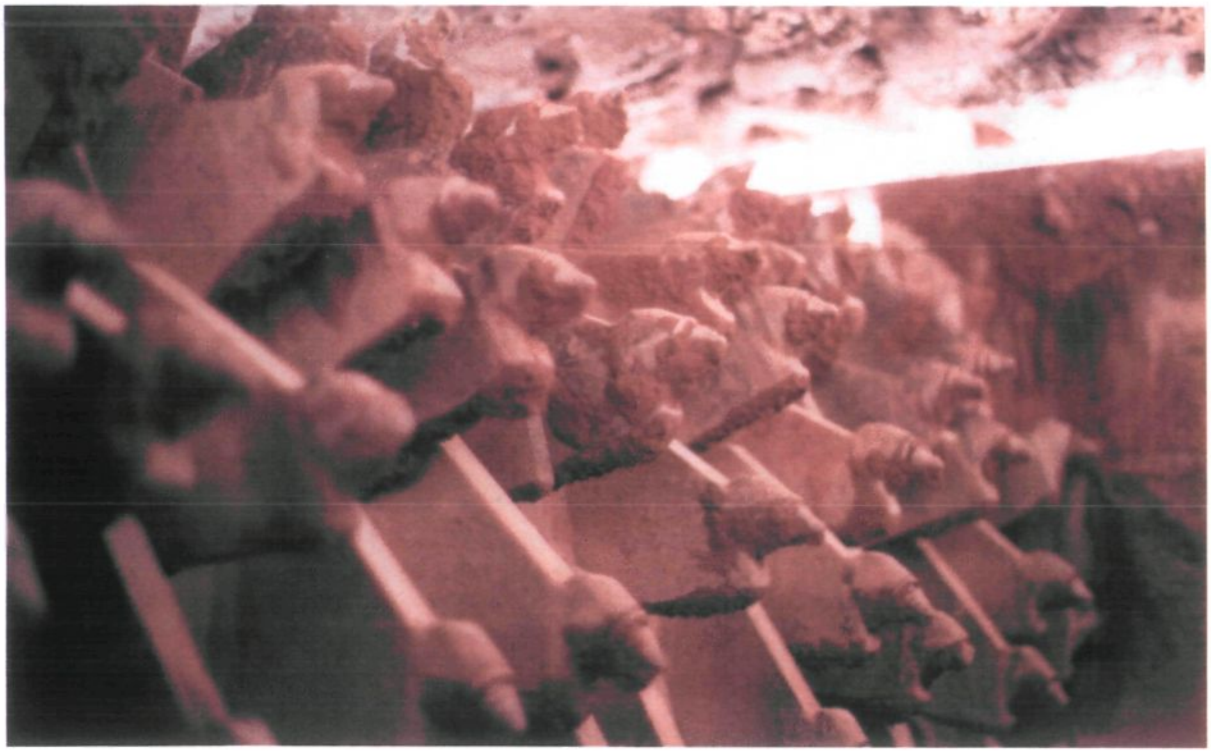
Following the release of the CMI RS-500, a German manufacturer introduced an even more powerful machine, the Wirtgen 2500K.

> 'The 2500K machine is a plant item for mixing which has a chamber where the binder is actually on board the machine itself and the binder and the gravel are mixed inside a chamber, so we now have gone away from having a separate spreading machine where the spreading is actually done by the one mixing machine altogether.' (Walter, Tape RTA-PRS:FH2, Side A, 17:47)

CMI RS-500 was the first of the 'work horses' used in deep-lift insitu stabilisation

Wirtgen RS-2500 reclaimer on its first project in Australia in Sydney's western suburbs, 1996

CMI RS-500 Reclaimer



Teeth of CMI RS-500 machine

The South Australian experience

Stabilisation of any significance in South Australia began in the early 1960s with bitumen emulsion in sandy soils in the southeast and east of the State. Bob Andrews is South Australian Principal Engineer at the Australian Road Research Board:

> 'I think what actually terminated all of that was the development of a lot of decent crushed rock quarries which allowed pavements to be reconstructed with granular overlay work.' (Andrews, Tape RTA-PRS:FH34, Side A, 11:47)

Although some lime stabilisation trials were held by the CSIRO in Adelaide's southern suburbs in the 1960s, it was not until the 1980s that stabilisation evolved as a rehabilitation treatment in South Australia. By this time, Andrews had become Pavement Design Engineer at Transport SA.

One of Andrews' successes has been the stabilisation of South Australia's unsealed road network - major freight and cattle routes - about 70,000 kilometres in length, for which he used chemical binders:

> 'It was done without the use of involving road recyclers or recycling machines – it was done by looking at binders that can be added to a water tank, rather than be spread out as a powder using a cement spreader, so it was limited in the parameters to try and maintain the cost and that's where the chemical binders came in to the fore in the sense that they can be added to the compaction water, either as a powder or as a liquid, and then spread out on the road, and then grader mixed. Standard practice for Transport SA, going back to what we call Dry Maintenance would have been grading a road every three months. They introduced Wet Maintenance, which involved putting down a network of bores, which provided access to water at 20km intervals and simply using water in the mixing and compaction technology, so that you end up with a tighter surface, which pushed the grading interval out to between nine to twelve months. The next stage of building onto that in terms of managing unsealed roads is to push the sheeting life out from 8-10 years to 15-25 years, and lifecycle models that you use show significant savings in extending the sheeting life, more so than the maintenance intervention period, so when you look at a network thing – managing the network, the use of these chemicals as an improver are quite valuable additions to the management of an unsealed road network.' (Andrews, Tape RTA-PRS:FH35, Side B, 33:37)

The first major stabilisation project Andrews was involved with on sealed pavements was on the Flinders Highway in 1987:

> 'It was about a 16 km length of rural pavement that had been damaged by the 1983 bushfires, actually, with carting all the logs that had been burnt and that sort of thing. The road was subjected to enormous traffic loading – all of a sudden, it wrecked the pavement, so insitu stabilisation was selected as the process, and it was all cement. Because it was 300 millimetres thick, we had to construct the thing in two layers and that really goes against everything else that happens in other States. That decision was based on the fact that we have a lot of cement treated bases in the metro area, which are plant mix materials, which are laid in two layers, but the two layers are actually laid in the same day, so that you create a bond, or you have more chance of creating a bond and secondly, because we are in a relatively dry climate, the ingress of moisture into the pavement – provided that there is adequate crack sealing

> maintenance and those sorts of things – make it a very successful process in South Australia. It's done in half-width construction to start with, so that the top half of the pavement, the top 150mm is removed and just cast onto one side and then the machine goes in and stabilises the subbase, or the bottom layer, and then straight away, the material that has been removed is replaced back again and the stabilised over the top in half width sections , same day construction, We've done a limited amount of post construction evaluation to determine bonding has occurred, so our experience has been that we've had... well, we've had no pavement failures that we know of that have been purely due to debonding. The reason why it performed so well, I believe is probably mainly due to the fact that we are in a dry climate, or most of our cement stabilised pavements operate in a dry climate, so therefore very few of them become inundated or saturated for any great length of time.' (Andrews, Tape RTA-PRS:FH34, Side B, 35:21)

Andrews was eager to embrace the brand new deep-lift Stabilisation technology and South Australia became the first State to boldly embark on a major stabilisation project in 1992, well before the NSW R&D trials had been completed and evaluated. The project chosen was the Dukes Highway, the main road between Adelaide and Melbourne:

> 'The Dukes Highway was reconstructed as a granular pavement through the seventies and eighties and the first section to be stabilised was actually the last section constructed, which was between Bordertown and the Victorian border – it was 16 km long and it was a granular pavement with very poor soft crushed rock – limestone – and within four or five years of construction, severe rutting, at least 50mm thick occurred in the pavement, so strengthening of the pavement needed to be undertaken to maintain safety, as well as other issues. The two options looked at were a granular overlay - and the granular material would have to come from 250 km away, meaning long hauls and expensive construction, and being a highly trafficked road, there are a lot of management issues with the construction. So stabilisation was considered and that was the way it went with cement – we did a mix design and it was four or four and a half percent cement – and it was constructed as a thick layer, which is the RS-500 or Wirtgen type new machinery that was around and heavy, 17-tonne vibrating pad foot rollers and done with all the available construction technology at the time. After stabilising the road, within a few years transverse cracking started to appear, which is quite usual for a bound pavement and some crack sealing interventions were done and slowly, longitudinal cracking started to appear, and the longitudinal cracks plus the transverse cracking induced the block fatigue cracking that we're familiar with and over the years that slowly extended from very short sections to something like 70% or 80% of the length now, I guess. During the course of that process, things like fabric seals to keep the water out of the pavement have been tried and they've been quite successful, actually, although pavement roughness is a bit of an issue with them. The pavement roughness issue was resolved by putting a slurry seal over the pavement and then putting a fabric seal on top of that. That hasn't performed too badly as a holding treatment. Foamed bitumen re-stabilisation was tried and that's performing very, very well, but the decision has to be made whether you can afford the process for the full length of the pavement and what risks you are actually adopting in terms of management of the pavement, because the worst thing you want is to re-stabilise a pavement and it fails again.' (Andrews, Tape RTA-PRS:FH34, Side B, 51:42)

So what went wrong with the Dukes Highway pavement?

> 'We have evaluated that pavement in terms of what was constructed. Basically, the design depth was 400mm and what we found was that the effective depth of the

> pavement was more like about 300mm, and that's due to compaction not being achieved in the bottom layers. The other issue associated with the construction of that pavement was that it was a single mix, whereas through the RTA trials particularly, it was found that a double mixing approach gave a much better blending of the binder with the materials. So there are a number of issues with that – just measuring the density with the quality control on the project with nuclear density meters – it's limited to 250mm depth, so you can't actually measure the density below that level, so you don't know what you've built, so there are a whole range of issues associated with the construction of that pavement that are not the same issues as if we went back and reconstructed that pavement as a cement stabilised pavement - it would be done differently as it is now.' (Andrews, Tape RTA-PRS:FH34, Side B, 57:07)

Andrews acknowledges that he was criticised for the failure of that pavement:

> 'There's nothing like a failure to turn people against the process and you're only ever remembered for your failures rather than your successes, and anybody that hasn't had a failure hasn't done too much engineering in my view. It was a failure from the view of performance – I think it was extremely successful from the point of view of a much greater understanding of how these pavements behave….. so if you put it in the context of the time, in consideration of the technology and the need to understand the technology and the performance of what you're building, regardless of the consequences I believe that it served as a platform upon which a lot of today's technology in South Australia particularly, has been developed.' (Andrews, Tape RTA-PRS:FH35, Side A, 00:35)

He recognises the risks associated with deep-lift Stabilisation:

> 'There are a number of risks associated with the process: the variability within the pavement itself, because you're dealing with old pavement, so as you're going along longitudinally, the pavement material or the subgrade changes and there are patches in the road which might be some other material and that sort of thing, so there's some of the disadvantages. The other issues, like trying to manage cracking in bound pavements has been partly resolved with modified binders and modified bitumen and those sorts of things, and even fabric seals to some extent – that's to try to improve the performance: you can't stop the cracking at the moment. Very little has been done in my view to actually try and construct a pavement without cracking - in other words, try and construct a stabilised pavement in the same sense you would with a concrete pavement, and that is to put joints in the thing.' (Andrews, Tape RTA-PRS:FH35, Side B, 53:15 & 54:56)

Andrews can foresee that kind of pavement developing within the next few years:

> 'This cracking is a big issue – not only due to hydration of the cement, which is one control, but also handling the thermal cracking in the pavement - in other words the summer-winter, expansion-contraction of the pavement. In a concrete pavement we deliberately put joints in the thing – in a stabilised pavement, we don't and to me, there is no reason why we can't engineer a joint in a stabilised pavement and still maintain rideability?' (Andrews, Tape RTA-PRS:FH35, Side B, 54:56)

Polymers

Water penetration is one of the big risks in single-layer deep-lift insitu pavements, with often one layer over a subgrade, so there is just one path for the water to go. The virtually explosive forces of a tyre over a saturated pavement can cause erosion of the subgrade and pumping of the material and those pavements can quickly deteriorate:

> 'Water usually comes up from the bottom. It will be pumped up by traffic going over it. If you can keep the water out of a material, you can build a road out of anything in my opinion. But water is the biggest curse of them all. Even if you've got a sealed road, traffic will pump water through the top and you'll find on the older roads, if you don't keep your sealing program up to date, seals get old, they oxidise and crack, and once the water goes in, that's the end of it. So water comes in from the top and the bottom.' (Harris, Tape RTA-PRS:FH15, Side B, 42:32)

When pavements crack, one solution is to use polymer-modified asphalts and bitumens, of which there are various types:

> 'The history of polymer-modified asphalts goes back to a person called Adolf Hitler and he ordered that he wanted roads built that he could move his Panzers quite quickly along roads which would not fail, and so German engineers came up with modifying the asphalts with polymers. That technology then died, presumably with the collapse of the German Empire and wasn't actually brought up again, certainly here in Australia until about the 1990s, when we started to use – not particularly polymer modified asphalt straight off, but scrap rubber bitumen in the asphalts.' (Walter, Tape RTA-PRS:FH2, Side A, 00:33)

Crumbed rubber is obtained from the recycling of old tyres, creating an environmental benefit in the process:

> 'During the seventies and eighties, I had a fair bit of experience with crumbed rubber, where crumbed rubber was put in and digested into the binder, and because it had much greater strain capacity, it would stretch and cover roads which were flexing a fair bit, and we used a lot of those to hold together the Hume Highway back in the mid seventies – the Hume Highway was falling apart – we used a lot of crumbed rubber to try and hold the highway together before we'd actually do a reconstruction,' (Bilaniwsky, Tape RTA-PRS:FH23, Side B, 55:00)

Polymers arrived on the scene in the early 1990s:

> 'There's a lot of good polymers around now that really help with poor quality materials in terms of giving them a bit of additional strength – certainly lowering their moisture susceptibility so that they don't lose strength when they get wet and they're starting to form a valuable part of the stabilisation market.' (Youdale, Tape RTA-PRS:FH32, Side B, 42:50)

> 'A lot of offices, after the primer seal will do the first permanent seal with a polymer modifier in the bitumen, so you might do a 14mm stone seal with a polymer. The polymer in the bitumen enables it to have a greater range of temperature before it gets brittle and reflects on a crack.' (Porter, Tape RTA-PRS:FH6, Side B, 30:51)

Tom Wilmot deliberates on the role that polymers will play in future stabilisation projects:

> 'I think that dry powder polymers will have a big influence on the market – they're being used extensively through the southwest of New South Wales at present. The product Polyroad, which is an Australian developed product, manufactured in Wodonga, is getting wide acceptance. It produces a fully flexible pavement – an unbound pavement – which means that you can often have thinner pavements than you can if they're a fully bound construction. It waterproofs the pavement, both from below and from above and provides the ability for materials to behave in their dry state, even through what would otherwise have been saturation.' (Wilmot, Tape RTA-PRS:FH19, Side A, 16:29)

Stabilisation across the Tasman

The history of stabilisation in New Zealand somewhat parallels that of Australia's. Robin Dunlop, now Secretary of the New Zealand Ministry of Transport, elaborates:

> 'They started in New Zealand in the wartime, 1943, 1944 at the airbase in Auckland. Then came the boom in the 1950s and 1960s, when there were a lot of roads being built - a lot of drive to get roads sealed. The National Roads Board started in 1954 and they had to get on with the job. By coming in with the stabilisers, we could just about mix it up in situ, tidy it up and seal it. Now that gave you perhaps another 15-20 years of pavement life, it was incredible, and it was so economical: that's where we cut the costs down by near up to half. What's interesting is that we don't do an awful lot of that nowadays - we're in a much better shape - our pavements are very compatible with anything in Australia in terms of roughness and so on: we do all these measures and we're as good as any state in Australia, even though we've got far worse soils and topography. We're still doing rehabilitation, but a limited amount, whereas in the seventies, we were having to do large lengths of pavement because they were just falling to bits. So it was a very good technique that was needed desperately at the time to make the money go further – the right thing at the right time.' (Dunlop, Tape RTA-PRS:FH36, Side A, 11:34 & Side B, 44:56)

In the late 1960s, stabilisation declined in New Zealand because of cracking in the pavements that had been built to date. In 1969, Dunlop started his Ph.D. research into stabilised pavements because people panicked about water getting into the pavements and the National Roads Board needed some answers. Dunlop's research was on soil/cement pavements:

> 'They're a mixture of naturally occurring material, like clayey sort of materials right through to sand to aggregates- they are mixed with cement in different proportions- from as low as one percent right up to ten or twelve percent. They had not used lime in New Zealand in a big way- they had done a few trials in the sixties, but most people thought this was a harebrained scheme and never took it seriously until I got into it in the seventies. I saw a great potential for lime and understood a bit about what it was doing, and did look at other additives too, I looked at chemicals, all sorts of....... but came back to the view that lime had a ...... you know, it was reasonably cheap. What we found there was that it was a lot more flexible material, didn't create high strengths, modified the clays and so on, and it had a lot more application, particularly for the low volume roads, and I even developed a technique for stabilising unsealed roads and leaving them unsealed and basically, what we'd do is, we'd grind up the subbase and then we'd put a bit of aggregate on top. We tend to develop a mosaic of aggregate on the top layer, so you can minimise the dust and wear characteristics and of course, the lime stabilised the pavement so much that it ended up running, almost like a sealed road - they were unbelievably good. Unfortunately, they were so good that some of the Councils I got them doing it went and put a seal on it, saying 'We might as well finish it off', which of course completely defeated the technique in many ways, but I think it had a lot of application in unsealed road situations. That was very pioneering work. No one had ever done that before. What we found is that the pavement is a very complicated environment. I don't think it had been adequately understood by many people just what is going on in the pavement. For instance, every day when the sun comes out, the pavement heats up, drives moisture down into the pavement and at night, of course, it does the reverse, so you have a whole lot of things going on in the pavement – that's just one thing – with a cement-stabilised material there are characteristics of drying and reacting with the

> cement that are different in different parts of the pavement, depending on depth of the pavement, water content of the pavement and also the loads on the pavement.' (Dunlop, Tape RTA-PRS:FH36, Side A, 11:34, 06:22 & 19:35)

Dunlop compares New Zealand's stabilisation experience with that of Australia's, and other countries:

> 'I think we tended to use the strength of the materials much more efficiently or perhaps more extensively and got more out of them than any other country in the world, because I don't think other countries really used the potential of the material as much as we did, you know - we really stretched the limit.' (Dunlop, Tape RTA-PRS:FH36, Side A, 25:17)

When asked whether Australia had perhaps taken up some of New Zealand's techniques, Dunlop replied:

> 'Oh absolutely, yeah. Australia was extremely slow at coming to the thin layer pavements rehabilitation – in fact, I did a number of lecture tours over there and they'd assured me that we had come unstuck in a big way - that of course did never happen and eventually, without any fanfare, I noticed Australia just adopting it without saying anything, just one of those things – you sit back and smile.' (Dunlop, Tape RTA-PRS:FH36, Side B, 56:30)

What had Australia adopted most of New Zealand's techniques?:

> 'A better understanding of what you can get away with, with lower grade materials, modified or even unmodified, I think. Overall they've.... and instead of having the view that you had to rebuild pavements every 25 years, that you can actually modify them by a thin layer over the top. We used a technique for quite a while, that we call seventy millimetres over the high spots, so in other words an unbound granular or a modified reliable cement-modified layer over the top, just to reshape the pavement – they just couldn't believe that you'd get away with that.' (Dunlop, Tape RTA-PRS:FH36, Side B, 57:39)

Safety and health issues

As with any construction technique, a number of significant safety and occupational health issues have been linked to stabilisation. These mostly concern the use of binders, such as lime, quicklime and tar, which first became an issue in the 1970s:

> 'The DMR had been using tar in the way of Paccal tar for precoating of aggregates for a number of years and that actually formed the best precoat that we've ever had and the most successful seal applications were done using Paccal tar, but the problem that we found……. people that were using tar pre-coating agents tended to get sunburnt, especially people with lighter coloured skins and one particular job I was on, we actually had to take one of the operators to the hospital, he was so badly sunburnt at the end of the day, and because of that it was decided that we'd ban the use of tar. Tar breaks down the resistance and increases the photosensitivity of the skin for UV radiation – around the body, it just allows the UV to get straight through. Tar, because of industrial problems with carcinogens fell out of favour quite quickly, so no more work was done in that area.'(Walter, Tape RTA-PRS:FH1, Side A, 25:55)

The use of lime also has identified risks:

> 'I think the safety issues these days are fairly minimal – there have been safety issues in the past, particularly with regard to the use of fine powders. In the good old days when lime stabilisation was started, the way it was done, the lime was delivered in bags - hydrated lime, which is a very fluffy powder – well, on a windy day out in Western New South Wales you had lime blowing all over the place: everyone was covered in lime – they had it in their eyes and it was very dangerous. In the 1970s, the use of hydrated lime sort of fell off and quicklime was used instead. Well now quicklime is a pelleted material, but when you add water to it, there's a great deal of heat and hydration that's released and that can burn you – burn the skin, so that became a major safety issue too.' (Youdale, Tape RTA-PRS:FH33, Side A, 15:53)

O'Meara recounts personal experience associated with the use of lime and quicklime:

> 'My skin is very bad, we have been burnt with quicklime. Out in the Hillston area there was four of us working there - we were doing quicklime – four of us ended up in hospital with burnt eyes, burnt skin. That is how powerful this quicklime is. It is stopped in the metro area now and I think in a couple of year's time, you won't even hear of quicklime again.' (O'Meara, Tape RTA-PRS:FH14, Side A, 15:54 & 23:35)

Slaking quick lime on the South Western Freeway between
Pheasants Nest and Avon Dam, 1979

Pulvimixer at work on the South Western Freeway between
Pheasants Nest and Avon Dam, 1979

Recycling and the environment

Recycling has always been a reason for using stabilisation. Resources are becoming scarce and there are new and stringent demands to manage our heritage and the environment. Therefore, recycling existing pavements makes a great deal of economic and environmental sense:

> 'Originally, stabilisation was popular in the fifties and sixties, purely from a cost point of view. Local Government and the DMR had a shortage of funds to build the rural network, or in fact the urban network, as Sydney sprawled into the Western suburbs. It was seen as a cheap process that didn't require new materials - we could have used the pavement materials in the road, so from that perspective, it met that initial requirement – it was cheap – and, as our road network gets older, we see ourselves in the same predicament. We've got a larger network, we've got a limited amount of funding, so we're still looking for cheaper processes. However, at the same time, in the 1990s we saw a couple of issues arise which were the drivers, and one was looking at sustainability of our environment – the ability to access the old quarries – can we dig up an old quarry anywhere? Well, the answer to that question now is: no, you can't for environmental reasons, for heritage reasons – and a lot of that was obviously driven by Mabo decision, but certainly the heritage and environmental reasons are probably the key drivers today for stabilisation.' (Vorobieff, Tape RTA-PRS:FH22, Side A, 13:50)

Australia is starting to run out of quarries- most good quality gravels have been used:

> 'If you look at the Princes Highway between Wollongong and the Victorian border, there are probably only two quarries close to that road, which is almost 600 km long and the challenge there is that you can't keep carting, from one side to another large amounts of quarried materials. You can't open a quarry quite easily without damaging the environment. All these aspects have to be taken into consideration, which then makes access and the cost to quarries starting to become cost prohibitive, so we have to look at better ways of utilising what's in the road.' (Vorobieff, Tape RTA-PRS:FH22, Side A, 17:22)

Ken Porter adds:

> 'There's a lot of recycling and there always has been in road construction, which is an interesting point. Quarry materials are expensive – engineers are about reducing cost; engineers, surprisingly are also interested in reducing scarce resources and reducing environmental impact of the works that they do. As far back as the 1960s and certainly the 70s, we were recycling crumbed rubber from tyres into bitumen as an enhancer for particular bitumen seals, and then later than that, in some asphalts. At the moment, there is up to 30% by volume of an asphalt that you see being put down in front of your house when they're resheeting the road might be old asphalt that's been ground up by a machine very similar to these stabilising machines, actually, called a cold mill and trucked back to the asphalt plant and incorporated with new aggregate and new bitumen in order to make new asphalt, so we've got something like twenty to thirty percent recycling in asphalt – that's accepted in roads specifications around Australia, and in other countries in the world too. So that's one type of recycling – there's also quarry product recycling in terms of concrete, so that concrete road pavements, concrete from buildings, concrete from wharves and bridges that are demolished are often put through a jaw crusher and recycled as a

road building material – they need modification and they need certain quality control, depending on what way they're going to be used.' (Porter, Tape RTA-PRS:FH6, Side A, 12:40)

'Resources are a very important thing. We shouldn't just be wasting the quarry products when there are now excellent products already in our roads – why not use those products by adding other qualities to them, so not only are we getting a cheaper product and saving the community money and giving them a good quality road, we are doing the right thing environmentally by recycling the material instead of digging more holes in the ground. You're saving pollution in terms that when you construct a road normally, you've got a fleet of trucks carting material away. That is all not only adding to the pollution by those trucks running, but you're also saving other roads, because those trucks have got to run over other roads, so you're also saving that as well. You're also saving tip space, because in days gone by, you'd excavate the road – that would go to a tip, you'd fill up your tip. Tips are in short supply – they now cost you a fortune to tip at - even your own tip. So again, it is saving tip space and that's an environmental benefit as well, so there's a whole lot of benefits all the way down the line by using this process.' (Ritchie, Tape RTA-PRS:FH29, Side A, 23:45 &Side B, 41:58)

'In the early nineties, we also saw a growing use of by-products from manufacturing and also in power generation, in particular the Hunter Valley – we were generating a lot of ash from the burning of coal, and what could we do with these waste products – can we use that to our advantage? So there was a lot of research and testing in the nineties to determine: could we utilise these products, Fly Ash, blast furnace slag, in terms of road construction? And the answer is yes, we've successfully used those for now well over ten years in road construction.' (Vorobieff, Tape RTA-PRS:FH22, Side A, 16:23)

Can recycled pavements be reused?

'One good thing about recycled pavements is that they can generally be recycled again. There are some challenges to recycling previously stabilised pavements, but there's been a lot of successful work done in that area and we believe that almost all of them could be successfully recycled.' (Wilmot, Tape RTA-PRS:FH19, Side A, 15:57)

Towed hopper spreading lime on the South Western Freeway
between Pheasants Nest and Avon Dam, 1979

Pavement Profiler at work on the Sydney Harbour Bridge, 1978

Stabilisation in other places

How have some of the other States fared with stabilisation? What has been Victoria's experience? Bruce Fenton is currently manager, Bituminous Surfacing at the RTA:

> 'They hadn't really gone down that path a great deal. Most of the stabilisation work tended to be in New South Wales and the Victorians tended to stick with their flexible pavements. They were building pavements up to 600mm thick in 150mm to 100mm layers and they had very good performance from these. We hadn't the same experiences from the flexible pavements built in New South Wales. Victoria has gone down a different path from New South Wales and controlled their flexible pavements a lot better and I think that they were definitely of a higher standard than the flexible pavements in New South Wales, but they were also significantly more expensive in the way they were built. Generally, these pavements were on large dual carriageway new works.' (Fenton, Tape RTA-PRS:FH7, Side B, 34:40 & 31:20)

> 'Queensland didn't use lime stabilisation to any degree at all – they were cement bound granular pavements. The ones that were done with good quality aggregates were generally fairly successful. There were others done with soil aggregates that had a fair degree of plasticity in them and they just frankly were too thin and not enough cement – roundabout 5% cement, and some of them had some fairly visible failures - the Ipswich Southern Bypass in particular has had a lot of failures and a large amount of that was dug up and replaced and there were some parts of the Gateway Arterial Road which cracked up a little bit sooner than was expected – that did cause a considerable backing away from a cement-treated base in Queensland.' (Dunstan, Tape RTA-PRS:FH11, Side A, 17:39)

> 'West Australia – I'm not sure much about Western Australia, I think they do a bit of stabilisation, but certainly not to the extent that New South Wales does, so I think New South Wales is still probably the State that does the most and I think Queensland still do a fair bit of stabilising.' (Bilaniwsky, Tape RTA-PRS:FH24, Side A, 23:15)

How does Australia rate against the rest of the world in its use of stabilisation, and in particular, the United States?:

> 'Generally, in the States their attitude to stabilisation was rather different. They tended to go for high strength and not necessarily worry about cracking from cement stabilisation. So they developed along a different line, and more along the line of high productions, high strengths, rather than our attitude of lower productions, higher quality and using it as a total pavement, whereas in a lot of American roads, it was only part of the total pavement.' (Wilmot, Tape RTA-PRS:FH18, Side B, 41:35)

> *Q: So were those American roads subject to more cracking than ours were?*

> 'Yes, most definitely, yes. The Americans accepted the cracking – they didn't see a problem with it, but it did put it in a bad light in regards to if you read about American work with their cracking, and the Australian engineers were horrified at the thought of cracks in their roads.' (Wilmot, Tape RTA-PRS:FH18, Side B, 42:31)

How much of Australia's practice in stabilisation has been influenced from other countries?:

> 'A major influence was the visit by Michel Ray for an Australian Road Research Board conference in 1986. He's a French engineer. France had a collapse of their road system after the Second World War and used an enormous amount of stabilisation and recycling prior to building their motorway system to get their economy moving again, including using granulated blast furnace slag, and they had track-mounted large recyclers before the lighter American ones that were introduced into Australia.' (Dash, Tape RTA-PRS:FH30, Side B, 07:17)

> 'Australia has tended to adopt United States practices when it comes to road stabilisation and in particular, cemented materials. We've adopted many of the Portland Cement Association's technical bulletins and guidelines over the many years, but once we started to venture away from traditional use of cement to the supplementary binders like Fly Ash and slag, we have tended then to look at our own research activities and techniques and develop our own guidelines suited to the use of those materials, and I thought in many cases, we've gone well advanced to countries like the US and European countries in using these better types of binders.' (Vorobieff, Tape RTA-PRS:FH22, Side B, 38:53)

In addition, there have been significant contributions made to stabilisation by South Africa:

> 'The South Africans have been a vast source of information for the last, probably 40-50 years and in fact a lot of the guidelines in the Austroads Pavement Design Guide have been adopted from South African work by De Beers and other engineers who have done a vast amount of research work. We have always looked on South Africa as a good source of information, primarily because they've got similar climates, similar materials, and to a certain degree similar practices that we would adopt in Australia.' (Vorobieff, tape RTA-PRS:FH22, Side B, 40:50)

> 'South Africa had a criteria that they wouldn't seal roads under a certain volume of traffic and they were using these lignant-based compounds as dust suppressants and if you added them from a water cart often enough, eventually you modified the gravel underneath, which will form the stabilisation, so they lead the world in that usage.' (Dash, Tape RTA-PRS:FH30, Side B, 07:17)

> 'I think one of the interesting challenges when we look around the world with Australia versus other countries is that our quality measures have been typically much tougher than other countries, such as the US and South Africa for that matter, and one of the practices we developed was better spreading techniques, more electronic load cells measuring devices, better vanes, better ways of evenly spreading the binder on the road. We've also had a harsher climate, so we've looked at better techniques for introduction of water and mixing qualities and procedures in that, so if anything, I think one of our greatest exports in that area has been the export of the construction processes, such that we get a better process carried out in the roadwork network, and I think that has been our greatest export is the construction of technology.' (Vorobieff, Tape RTA-PRS:FH22, Side B, 43:59)

> 'I believe we know a lot more about insitu stabilisation than most other countries. Certainly the French are well developed with pugmill type stabilisation and higher grades of stabilisation. We've had the huge disadvantage in Australia of having a large road network with a low population base, so we need to develop roads at a very low proportion of our total budget expenditure and this is coupled with a lack of natural materials, particularly in country areas. It has developed a need to stabilise and from

that need we've become a lot better at it. We now have Australian expertise being used to develop stabilisation – in particular around Asia – we have operations in Malaysia and Brunei and some large projects in Indonesia, which are all based on Australian technology. (Wilmot, Tape RTA-PRS:FH18, Side B, 43:12)

'Stabilisation in Australia, by comparison with the rest of the world is now probably streets ahead of the rest of the world – its technology is much more highly developed in terms of insitu stabilisation for the type of pavements we have in Australia.' (Andrews, Tape RTA-PRS:FH35, Side A, 09:03)

The Pavement Design Guide

Pavement design methods have now been accepted in all States of Australia and the standards are specified in the Pavement Design Guide. That publication, now so important, has travelled a long and difficult road:

> 'It started actually in the mid 1970s, where, at that time each road authority had its own pavement design method and there was a working group set up under NAASRA, which is the National Association of Australian State Road Authorities to try and bring these together and have a national pavement design procedure. It was generally thought at the time that this would be a simple matter, that we'd put them all together in a book and pin them together and everyone would accept it. It turned out to be a much more complex matter than that and agreement couldn't be reached, so in - I think it was 1981 - there was an Interim Guide to Pavement Thickness Design, that was issued on a very limited basis by NAASRA for comment, but it wasn't accepted by anybody. At the same time, there was a Working Group set up to carry that forward to become a national guide. I was fortunate enough to be a member of that Working Group – we toiled away for seven years to actually produce this, but the pavement design methods up until then were all Empirical methods that were based on the past. They were all unreliable, so this Working Group worked on what's called the Mechanistic procedure in which the pavement is considered as an engineering mechanism, so when that was published in 1987, it was a pretty major step forward in terms of pavement design and it was adopted by all the road authorities, albeit that most road authorities wrote a supplement to it to tie it in to their own materials specifications and how they viewed the world.' (Youdale, Tape RTA-PRS:FH32, Side B, 29:55)

Bob Andrews, as a member of the Austroads Working Group for the past 7 or 8 years is currently engaged in rewriting the Austroads Guide to Stabilisation, likely to be published at the end of 2005:

> 'An initial version was published in 1998 just to catch up with the fact that deep-lift Stabilisation was here with us now and this represented the current state of knowledge at that time. Since 1998, there have been all these major developments occurring in the understanding of pavements, mix designs and pavement designs, so that brings the Guide up to 2005, it will be. I'm currently the principal author for that work. The Guide will have a lot more formal direction in terms of selecting the type of binder suited to the most appropriate application or the most appropriate pavement – in other words, it will give directions as to when a bound pavement is the most suitable pavement, or whether a modified or lightly bound pavement is the most suitable pavement. It will then go into a semi formal, or flow-chart type process of how to go about defining which binder and how much binder you would require for that particular application, and then it follows into formal pavement design: how thick it's got to be, what sort of activities you undertake on the site to determine subgrade conditions, or the existing pavement condition if it was an insitu pavement: how to sample it and do all sorts of things. It has a lot more on lifecycle costing, so you can look at various options over the life of the pavement and actually determine which one is the most cost benefit appropriate to your situation, so it gives a lot of direction in that area. It expands on the construction section in the sense of recognising new equipment and capabilities and also in the Quality Assurance/ Quality Control area of electronic gadgetry that control some of the processes, as well as the ISO 900 Series of Quality Assurance Systems band there are a number of

standard qualifications written now which are Australia-wide, or AustStab documents Australia wide that will direct the reader to assistance, that allows him actually to get to some stage where he can make a decision, or call a contract, even. The one major new section of the Guide is actually in the Maintenance side, in other words, having built a pavement, there is a totally new section on the expectation of that pavement in terms of its distress and performance mechanisms and the various technologies that are around to actually manage those, in terms of increasing or maintaining the surface life of the pavement.' (Andrews, Tape RTA-PRS:FH35, Side B, 42:12)

Education, training and research

Teaching stabilisation in university engineering courses began in the 1960s when Dennis Orchard, Professor of the School of Highway Engineering at the University of New South Wales taught the subject. Orchard and his students looked at cementitious stabilisation and at Fly Ash and other pozzolanic materials:

> 'The first work that I was aware of was done either in the School of Highway Engineering or in the Institute for Highways and Traffic Research that share the same laboratories and same buildings and that work was certainly well in progress in the 1960s and continued through the 1970s at least. I think by the 1980s it effectively ceased because the Institute and the School of Highway Engineering were absorbed into Civil Engineering, the laboratories were dismantled and one of the casualties of that was research into stabilised materials.' (Shackel, Tape RTA-PRS:FH38, Side A, 09:30)

Was there much taught about stabilisation in University of New South Wales Engineering courses?:

> 'At the postgraduate level, yes. The students who studied for Master of Engineering Science and Highway Engineering were certainly taught this – they still are, but at the undergraduate level, it would be perhaps less than one hour in total spent on it. (Shackel, Tape RTA-PRS:FH38, Side A, 19:23)

Shackel can recall seminars held at the School of Highway Engineering in the 1960s and 1970s where stabilisation was a major theme:

> 'I can also recall the School of Highway Engineering hosting overseas experts - Professor Yamanouchi from Japan, who had made some quite innovative techniques in stabilisation; closer to home, Robin Dunlop from New Zealand, people like Owen Ingles from the CSIRO, Dr Croft – a whole number of people were involved in these seminars. Professor Yamanouchi came up with something which is not sufficiently well known in Australia: he found it was quite crucial when you first allow traffic to run on these pavements after they've been stabilised, and essentially he found that either you should put traffic on immediately the road has been stabilised, or you should keep it off for three or four days. What you shouldn't do is to keep it off for one or two days and then allow the traffic to come on. Now I think that has practical implications in some of the Local Government areas where they use stabilisation as a means of rehabilitating the existing roads. The worst thing you could do, according to the research that Yamanouchi did, for example, was to stabilise the road on a Friday, leave it closed to traffic over the weekend and then open it on Monday, so there are a few refinements like that that deserve to be better known.' (Shackel, Tape RTA-PRS:FH38, Side A, 21:35 & 56:27)

Training of young engineers has become an issue for David Dash:

> 'It's a matter of continuity, because as the road authorities move to road managers, rather than the doers – the doers are the contractors – and yet those are the people who have the operations experience and will eventually be your technical advisers and contractors could be building a dam one month, a high rise building and a road

the month after and gaining the continuity out of the workforce when it is so mobile is an issue. It means that you happen to train a whole lot more people for a whole lot of short term projects and that means more training when time demands are greater, and so overall you have more people knowing less about the detail. There is a shortage of people with long term experience in stabilisation.' (Dash, Tape RTA-PRS:FH30, Side B, 15:06)

'I did stabilisation in my course in the sixties, but they only teach you the basics- they can't teach you the experience or the fine points of the processes and what goes into making the decisions: they usually give you the broad outline and then you go out there and apply it and learn from it and I think what we're missing these days, due to the structuring of our organizations is the real experience that people can gain out in the field – as engineers, we should not lose that ability of going out there and trying things and trying to go to the limits of the process in some cases and not just sitting on our old methods and saying 'That's all we know - we know how to build those.' because that's exactly what happened in the sixties in Bankstown and they learnt from that and ventured into stabilisation. I have to say – and I've said this at forums already – that we're relearning: we're going back and relearning what we learnt in the sixties, and I think that's a shame, that's a waste of our knowledge and resources.' (Ritchie, Tape RTA-PRS:FH29, Side B, 33:05)

Research and development undertaken by road authorities and industry is also in decline:

'The amount of Research and Development has dropped off in the state road authorities and Austroads in the past few years. This is probably due to the swing away from emphasis on the technical to emphasis on managing the road asset and I think it has dropped away in a lot of areas and stabilisation is one of those. I think it does have an implication, because a lot of the materials research that was done – it's an evolutionary thing. I think probably the deep-lift stabilisation was as close to revolutionary as you get in these matters - it was a significant step that happened in a short period of time, but a lot the work done on materials is evolutionary and because the road authorities spend so much money on maintenance and construction, there is a benefit cost in these research programs that seems to have..... the idea of that seems to have been lost to a certain extent – the research effort has sort of faded away as a result of that, which in my personal opinion is not a good omen for the future.' (Youdale, Tape RTA-PRS:FH33, Side A, 00:22)

How does Professor Shackel think Australia's research work in stabilisation is regarded overseas?

'I doubt if very much of it is known overseas. I think people are more likely to be aware of work done at American universities like Texas A & M – this work is much more widely known than work here in Australia. I don't think Australia is regarded as a leader in stabilisation- I think the French probably are: the French have used it more widely and they've also been more innovative in what they've done. For example, the French have successfully combined their use of bitumen and cement in stabilisation. The Central Laboratories for Roads and Bridges are extremely well equipped – they've done a lot of testing. It's not perhaps as well known as it should be, because a lot of it is published in French.' (Shackel, Tape RTA-PRS:FH38, Side A, Side B, 44:23)

Future challenges

What might the future bring for stabilisation and how will it survive the many challenges ahead? Ihor Hinczak:

> 'The future challenges in stabilisation from my perspective is on two fronts. One is the designer binders that will allow much more insitu stabilisation in utilising the material that isn't deemed to be suitable, so that you don't have to bring external products in. The other part of that is – and it sounds like a contradiction – is the greater utilisation of co-products in some of the materials that may not be suitable for use in concrete but may find their way into pavement structures and areas like that. From the binders' side, I think it's a development of materials that will allow the design engineer to achieve the properties they are desirous of. There is no panacea – you cannot just simply say Portland cement-tied binders are the best and you cannot say that organic binders like bitumens and emulsions are the best – I think we have to start looking at: can we get the properties of each of those two different species into the one species - in other words, get a real tailored binder that gives the engineers the ability to design the pavement that they really want with the confidence and the knowledge that they are going to get the results? (Hinczak, Tape RTA-PRS:FH21, Side A, 09:54)

Geoff Youdale adds:

> 'The basic techniques are pretty well laid down now – there's still some work, probably needs to be done in terms of improving construction practices. It doesn't take a lot of poor construction practices to produce a poor product. It's very essential that you get the full density, it's essential that you get a good ride quality so that you don't get dynamics on it, its essential that you mix the binder into the pavement material and its absolutely essential that you cure it properly. So there's a number of areas there that can go wrong and I think Quality Assurance is an area that's still evolving to my mind. It is a rather specialised technique and there's quite a bit of expertise in building these things properly.' (Youdale, Tape RTA-PRS:FH33, Side A, 09:57)

Mal Bilaniwsky sees challenges in pavement maintenance:

> 'I certainly see stabilisation has a very big part to play in road maintenance. Like everything else, it has its strengths, weaknesses – it has limitations, it has its niche where it's suitable to use. One of the concerns I have is that after eight or nine years we're often getting these rift valley failures, where we haven't had enough cover over the subgrade and in operations, if you don't pick up the fine cracking early enough, moisture does get in and you have the erosion of the fines, so we've got to look at ways of either picking up our cracking earlier or changing our cycle time for the reseal from the eight, nine or ten years back to about five or six years – that's what we're looking at, at the moment.' (Bilaniwsky, Tape RTA-PRS:FH24, Side A, 00:22)

> 'I think we'll see two vast improvements in the next ten years – one is the delivery of the binder. There'll be better techniques in how we'll deliver it, whether it's a powder form, liquid form, or capsule for that matter, or some other form. We'll also see a better ability in the mixing process – how we can mix it quickly without causing

> disturbance to buildings, or whatever and compact the material.' (Vorobieff, Tape RTA-PRS:FH22, Side B, 54:04)

Mal Bilaniwsky also sees challenges in spreading:

> 'The issue there is spreading the additive – after you've spread it, the RS-500 itself, as it tracks through it, the wheels itself compress the material as it rides over it. The material can move on grades, it can flow down or across the road. You can create bow waves in the course of trying to stabilise it, so getting the consistency of additive spread uniformly across the pavement, then vertically incorporating it so that it's uniform over 360 (degrees) is still one of the greatest challenges.' (Bilaniwsky, Tape RTA-PRS:FH24, Side A, 06:30)

What sort of an impact is the increase in traffic loadings going to have on stabilisation?:

> 'As we get to these heavier vehicles being trafficked we need a surface layer which can cope with these higher tyre pressures and repetitive loading. We're looking for materials such as asphalt or concrete that can support and sustain those heavy tyre loadings at the surface and also in depth and in order to make those surface materials work well, they also have to be compacted, so we're looking at some base materials that are stiff themselves and this is where stabilisation's a very good option because it offers the surface materials the ability to compact on a better surface layer down below, so we're looking at stabilisation in that process. And then we're looking even deeper: we want our subgrades to perform over a forty year period and we're looking at modification or a low form of stabilisation at the subgrade surface levels, so that we can make sure that they're not subjected to changes in moisture and swell, etc. So stabilisation, when we look at the heavy traffic spectrum performs well in those lower layers, so that it supports and gives strength to the upper layers.' (Vorobieff, Tape RTA-PRS:FH22, Side B, 52:06)

Asked what his worst nightmare as an Asset Manager might be, Bilaniwsky gave this reply:

> 'Trucks consume pavements – cars don't. We provide capacity for cars but the pavement is designed for truckloads, because one truck can do the damage of ten thousand cars, or one axle of a truck can do the damage of ten thousand cars. So we design for pavements, and when we look at the network on New South Wales roads, the average age of pavements is well over twenty years. Network development adds about one to one and a half percent of new pavement per annum and at the moment we are recycling pavements on a State-wide average around one and a half or one point three percent per annum where we are targeting three percent plus, which gives you a cycle turnover of about every thirty three years. We're getting back to about recycling our pavements at the moment, renewing our pavements getting close to one every 100 years on pavements which probably on average, have already exceeded their use-by date and truck traffic is compounding at six percent per annum on those State networks in terms of the loading, so our worst nightmare is that we're slowly, bit by bit, falling behind, so we're out there, trying to slow down that rate of deterioration by keeping our drainage and resealing up and we're trying to use all the techniques we can to, when we reconstruct a pavement, making it cost effective and cheap and give as long a life as possible and that's the challenge – it's the challenge for the RTA, not just here, across the State. It's all increasing, the infrastructure is old and we're trying to reconstruct our pavements and so we've got to keep that network going under load – that's the challenge.' (Bilaniwsky, Tape RTA-PRS:FH24, Side A, 13:49)

In this oral history project, it has been recorded that the RTA sought a capacity for deep-lift stabilisation on the basis of mechanistic pavement design and proceeded to fund a full-scale trial under the R&D program. It received the cooperation of industry for five trials across NSW, which proved capacity and cost advantages, and encouraged industry to invest in new and more powerful equipment and improved stabilization procedures. That initiative has since resulted in many hundreds of kilometres of recycled highway pavements in New South Wales. It was a passage from research to practice in only two years - a rare occurrence in the infrastructure industry and a credit to all involved in that process.

The opinions expressed in the oral history interviews and summarised in this report are those of the individuals concerned and do not necessarily represent in whole or in part the position of the New South Wales Roads and Traffic Authority.

List of Interviewees

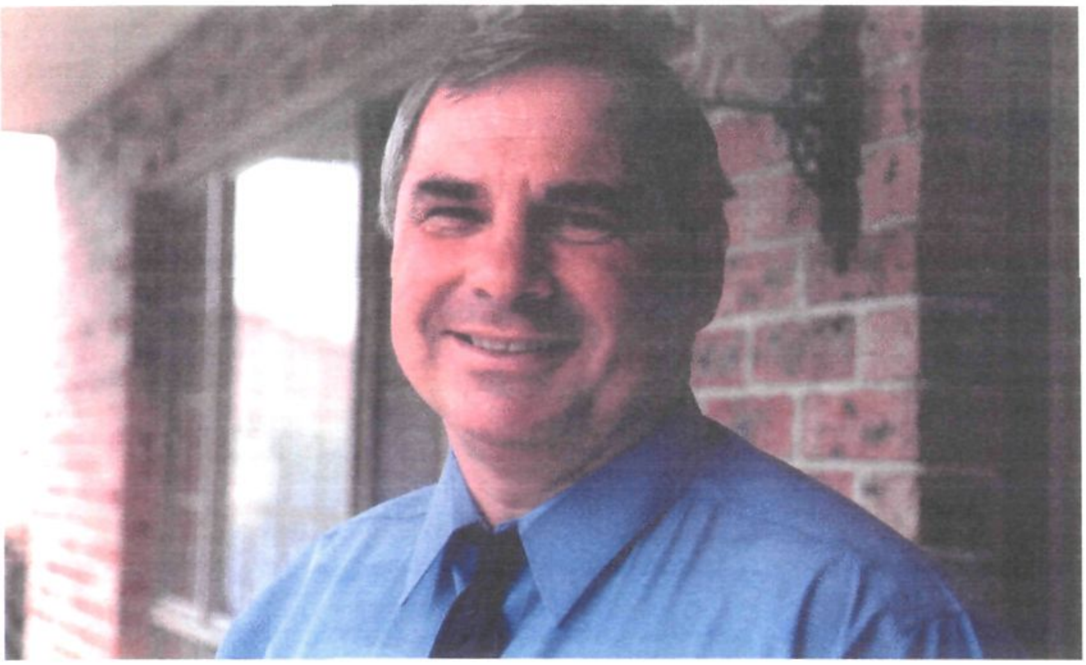
Name	***Tape No.s***	***Date***	***Place***	***Duration***
Phil Walter	RTA-PRS:FH1-2	27/10/2003	Cremorne NSW	87 mins
Warren Smith	RTA-PRS:FH3-4	27/10/2003	Cremorne NSW	85 mins
Ken Porter	RTA-PRS:FH5-6	29/10/2003	Cremorne NSW	100 mins
Bruce Fenton	RTA-PRS:FH7-8	06/11/2003	Cremorne NSW	89 mins
Ron Hocking	RTA-PRS:FH9-10	10/11/2003	Ballina NSW	79 mins
Trevor Dunstan	RTA-PRS:FH11	11/11/2003	Alexandra Hills Qld	59 mins
Ron McLaren	RTA-PRS:FH12	12/11/2003	Cremorne NSW	52 mins
Allan O'Meara	RTA-PRS:FH13-14	14/11/2003	Cremorne NSW	95 mins
Greg Harris	RTA-PRS:FH15-16	24/11/2003	Wagga Wagga NSW	74 mins
Brian Hanson	RTA-PRS:FH17	24/11/2003	Wagga Wagga NSW	55 mins
Tom Wilmot	RTA-PRS:FH18-19	25/11/2003	Cremorne NSW	88 mins
Ihor Hinczak	RTA-PRS:FH20-21	27/11/2003	Cremorne NSW	73 mins
George Vorobieff	RTA-PRS:FH22	28/11/2003	Cremorne NSW	57 mins
Mal Bilaniwsky	RTA-PRS:FH23-24	01/12/2003	Coachwood Park NSW	85 mins
Val Brizga	RTA-PRS:FH25	01/12/2003	Coachwood Park NSW	85 mins
Doug Prosser	RTA-PRS:FH26	01/12/2003	Coachwood Park NSW	49 mins
Greg Johnson	RTA-PRS:FH27	03/12/2003	Cremorne NSW	47 mins
Paul Ritchie	RTA-PRS:FH28-29	04/12/2003	Baulkham Hills NSW	101 mins
David Dash	RTA-PRS:FH30-31	05/12/2003	Cremorne NSW	79 mins
Geoff Youdale	RTA-PRS:FH32-33	09/12/2003	Cremorne NSW	79 mins
Bob Andrews	RTA-PRS:FH34-35	08/01/2004	Semaphore Park SA	118 mins
Robin Dunlop	RTA-PRS:FH36-37	22/01/2004	Wellington NZ	75 mins
Brian Shackel	RTA-PRS:FH38	23/02/2004	Cremorne NSW	59 mins

Interviewees' biographies

Bob Andrews

Bob Andrews came to Australia from the UK in 1959 and became a qualified draftsman. He studied Engineering and graduated in 1970. After joining the Department of Transport, he managed their test laboratory and determined mix designs for pavement stabilisation, becoming Transport SA's Pavement Design Engineer in 1984. He introduced Mechanistic design methods in South Australia and one of his major projects was the stabilisation of the Flinders Highway in several layers, thereby pioneering new bonding techniques. He was one of the first persons in Australia to use deep-lift insitu stabilisation using the new recyclers in the early 1990s. More recently, he used chemical binders to extend sheeting life for the 70,000 km unsealed road network in SA. Bob is Principal Engineer with the ARRB in South Australia and is currently engaged in rewriting the Austroads Guide to Stabilisation to be published in 2005.

Mal Bilaniwsky

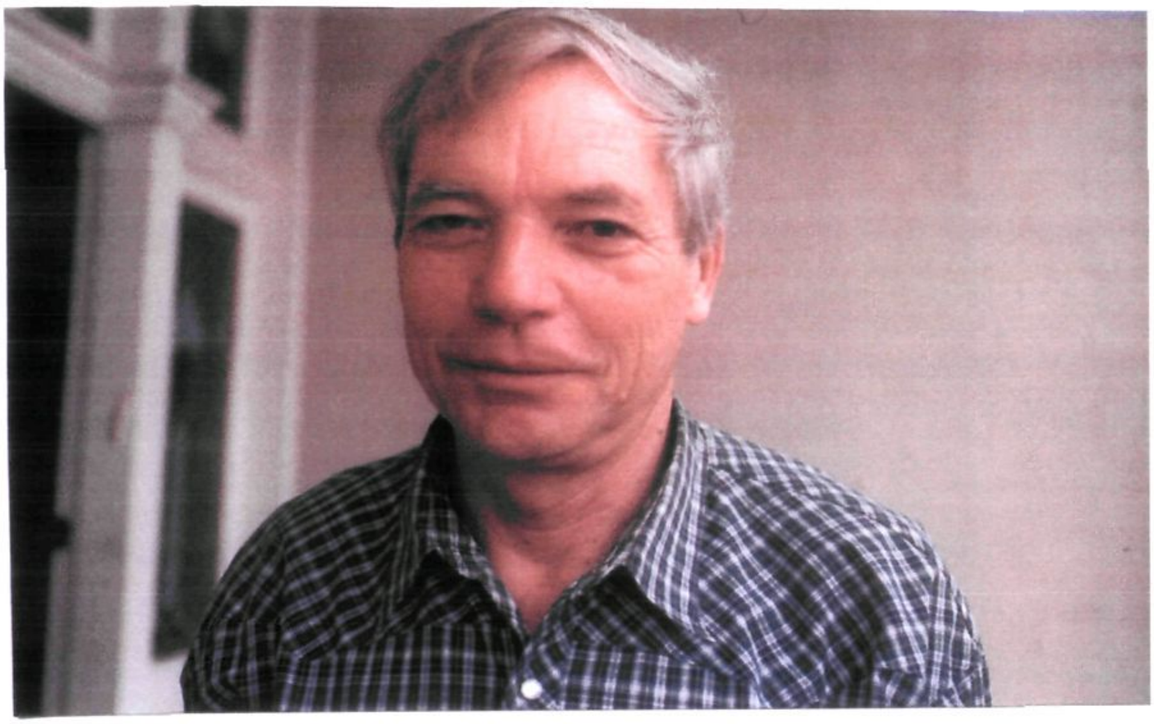


Mal Bilaniwsky is Australian-born of Ukrainian origin and his parents came to Australia as refugees after the Second World War. The DMR offered him a cadetship and he started work at Bellambi Works Office in 1971. He pioneered the use of slag pavements and slow-setting additives on the South Coast and was involved with the ALF trials at Numeralla. He is in the forefront in the use of crumb rubber and polymer seals. Mal is currently Asset Manager at the RTA's Southern Regional Office in Wollongong.

Val Brizga

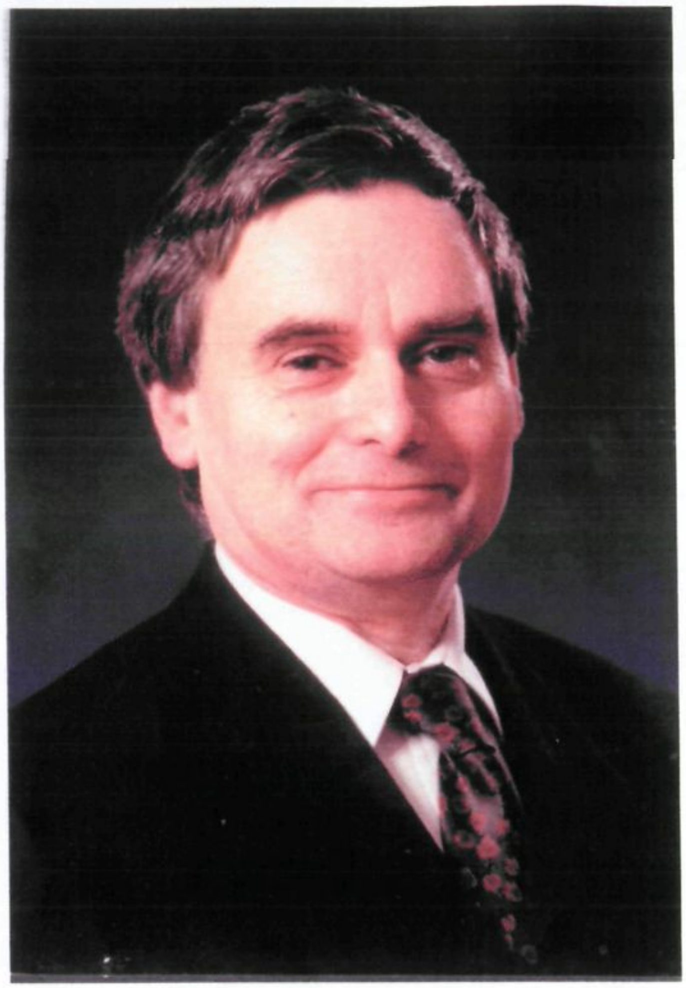
A geotechnical scientist at the RTA's Southern Regional Office, Val Brizga was always interested in geology. He started with the DMR at Glen Innes Divisional Office in the geotechnical laboratory. His work with the DMR and RTA includes landslide investigations, the investigation of new routes and he has been deeply involved in the development and analysis of new binders and slow-setting additives.

David Dash



David Dash was born in 1943, attended Fort St High School and then studied Science and Civil Engineering at the University of Sydney. After an interesting and distinguished 44-year career with the RTA, David retired in 2003 as General Manager, Pavements Branch. He has been involved in every aspect of pavement management.

Robin Dunlop



Robin Dunlop grew up on a dairy farm on New Zealand's Canterbury Plains. After finishing a degree in Civil Engineering, he commenced research work on the characteristics of soil/cement stabilisation for his Ph.D. in 1972. He developed a successful technique for stabilising unsealed roads, introduced lime into New Zealand's stabilisation practices and by using stabilised layers, was able to save millions of dollars in reconstruction costs. He continued his research work on pavement design and moisture movement within pavements and became Chief Executive Officer of Transit NZ where he established a close working relationship with Australia through AUSTROADS. He is a strong advocate of recycling and is presently Secretary of the New Zealand Ministry of Transport.

Trevor Dunstan

Trevor Dunstan completed a degree in Mechanical Engineering at the University of Queensland and helped to design engines for the Ford Motor Company in Geelong, Victoria. At the age of 23, he had attained a position as Assistant Chief Engineer for a bulk materials handling firm. In 1977 he started Aran International and is credited with having designed and built the first Aran pugmill, which became a benchmark in the stabilisation industry.

Bruce Fenton

Bruce Fenton studied Civil Engineering and Computer Science at the University of New South Wales and started his career with the DMR as Assistant Works Engineer at the Goulburn Divisional Office in 1986. In his early work he was engaged on the reconstruction of the Hume Highway and Federal Highway. He has particular knowledge and experience in the use of blast furnace slag. Bruce is currently Manager, Bituminous Surfacing at the RTA.

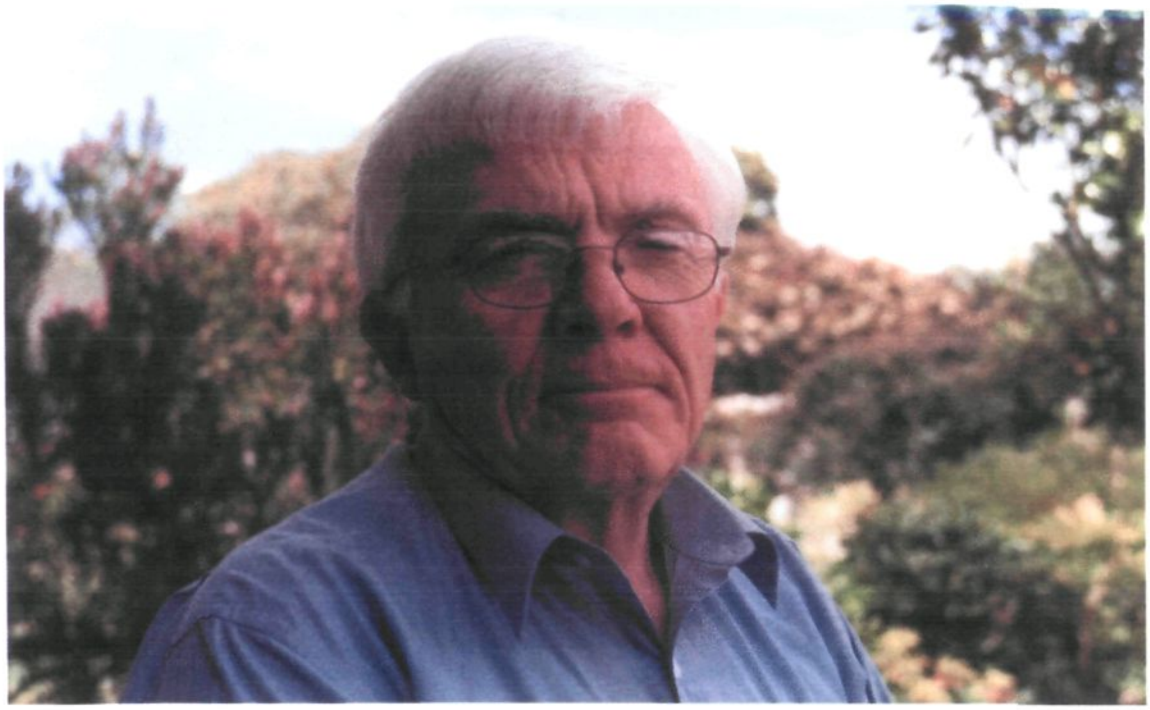
Brian Hanson

After completing a Civil Engineering course in 1971, Brian Hanson commenced his career with the DMR as Assistant Works Engineer at the Finley Works Office. He gained valuable experience in setting out roads, worked on the Cobb Highway and became involved in bridge maintenance, He constructed upside down pavements for the Gobba Deviation and new dual carriageways for reconstruction of the Hume Highway. He is currently Project Manager for the new crossing of the Murray River at Robinvale/Euston which will link Robinvale with the Sturt Highway.

Greg Harris

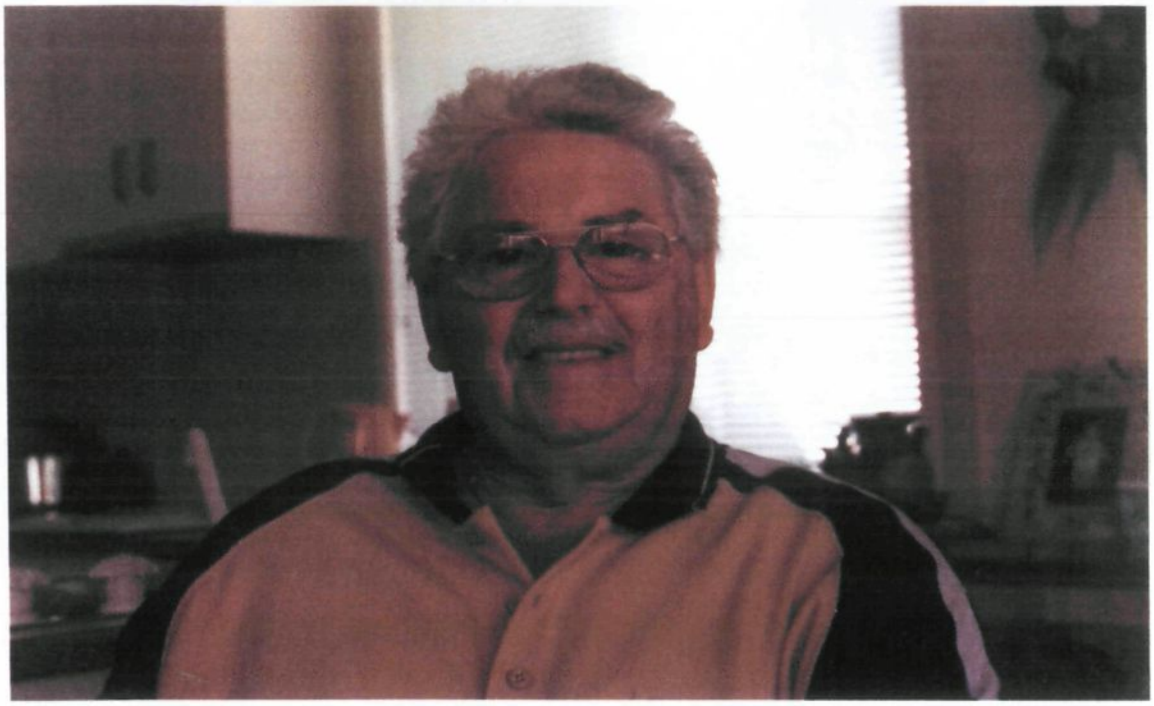
Born and educated in Tumut, Greg Harris' father worked as a plant operator on the Snowy Mountains Scheme in the 1950s. After leaving school, Greg found a job with the Snowy Mountains Authority on the construction of Talbingo Dam in 1968. He then moved to Holbrook where the DMR employed him to work on the Hume Highway in road maintenance crews. He has operated all kinds of heavy machinery, knows every metre of the Hume Highway from Tarcutta to the Victorian border and has an extensive knowledge of stabilisation techniques. He is currently Superintendent, Maintenance at the RTA's Wagga Wagga office

Ihor Hinczak



Ihor Hinczak graduated in 1969, having completed a Bachelor of Science and Master of Engineering degree on slag products. He then gained a Ph.D. in the properties of cement slag, fly ash and silicofume. Hinczak became a technical expert in the use of cement and slag and among his projects are the Sydney Opera House, Australia Square Tower, Jindabyne Tunnel and the North West Cape Gas and Oil Project. He is currently a private consultant and principal of Cementech Pty Ltd.

Ron Hocking

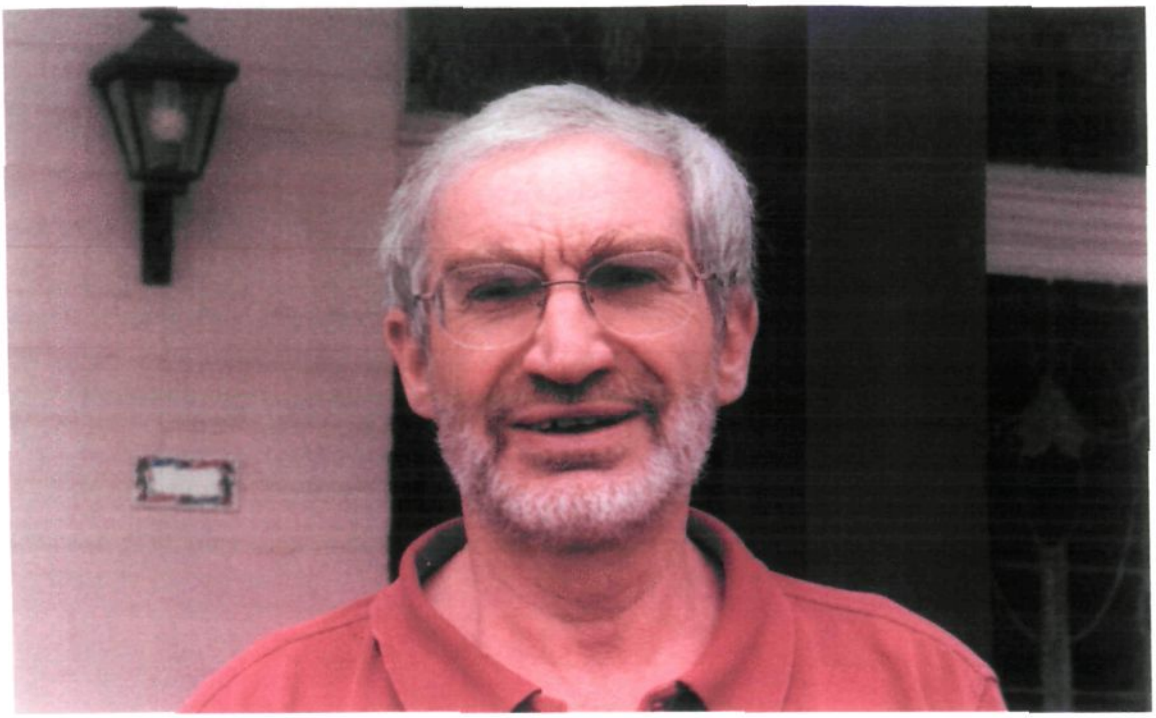


Ron Hocking is a self-made man. He left school at a young age and had a number of jobs until he was offered a position at MacDonald Constructions where he performed tests on compressive strength, moisture & PI content of soils. He worked with insitu stabilisation at a time when few were doing it and Tullamarine jetport was one of his projects. He was involved in the first foamed bitumen work carried out in Australia for Mobil Oil and has stabilised many large infrastructure projects, including the Moomba gas fields.

Greg Johnson

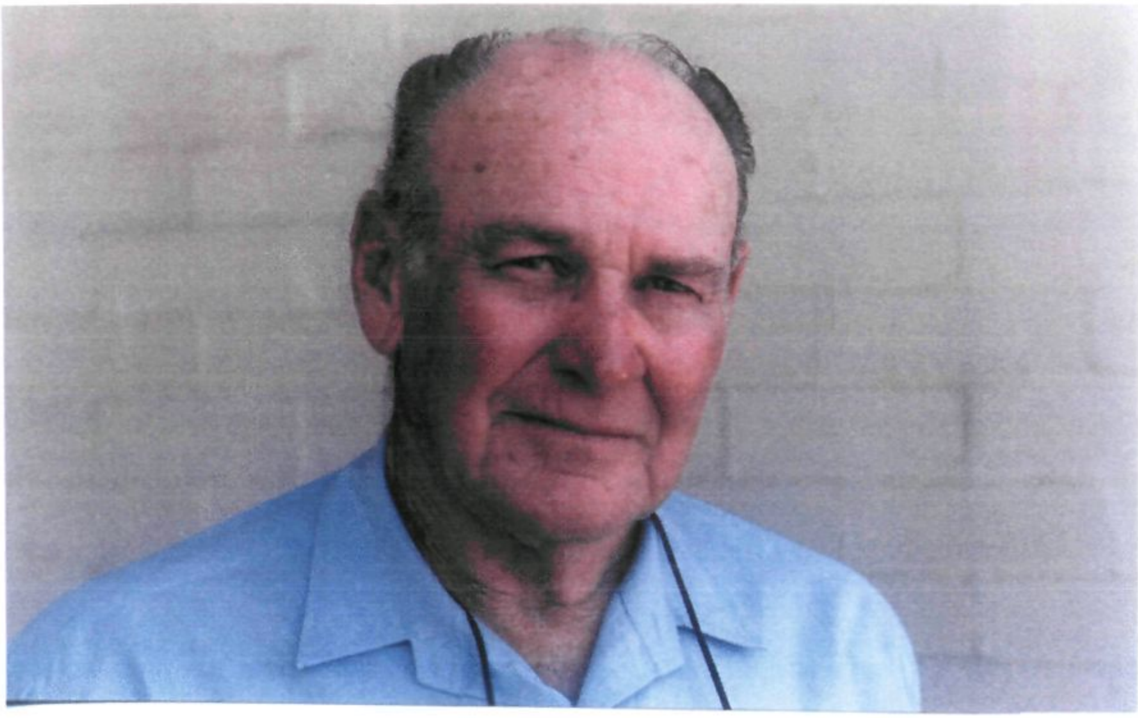
Greg Johnson joined Readymix' research laboratory as a plant chemist in the 1970s and analysed chemical admixtures for concrete, road blends, flyash and quarries. In the 1990s, he invented the so-called Triple Blends after they were promoted at an RTA conference and a waterproof blend for roads called Flexblend. He also developed various kinds of cement retarders which substantially increased the setting time of cement. Greg is now Senior Development Scientist at Rocla.

Ron McLaren



Starting in the Readymix laboratory in 1970, Ron McLaren became an authority on concrete and is probably Australia's foremost flyash expert. He set up Flyash Australia and then worked under the Boral and CSR joint venture. Now Manager, Cement & Fly Ash for Hyrock, among his projects are the cement used in the MLC Tower in *Sydney's CBD*,

Allan O'Meara

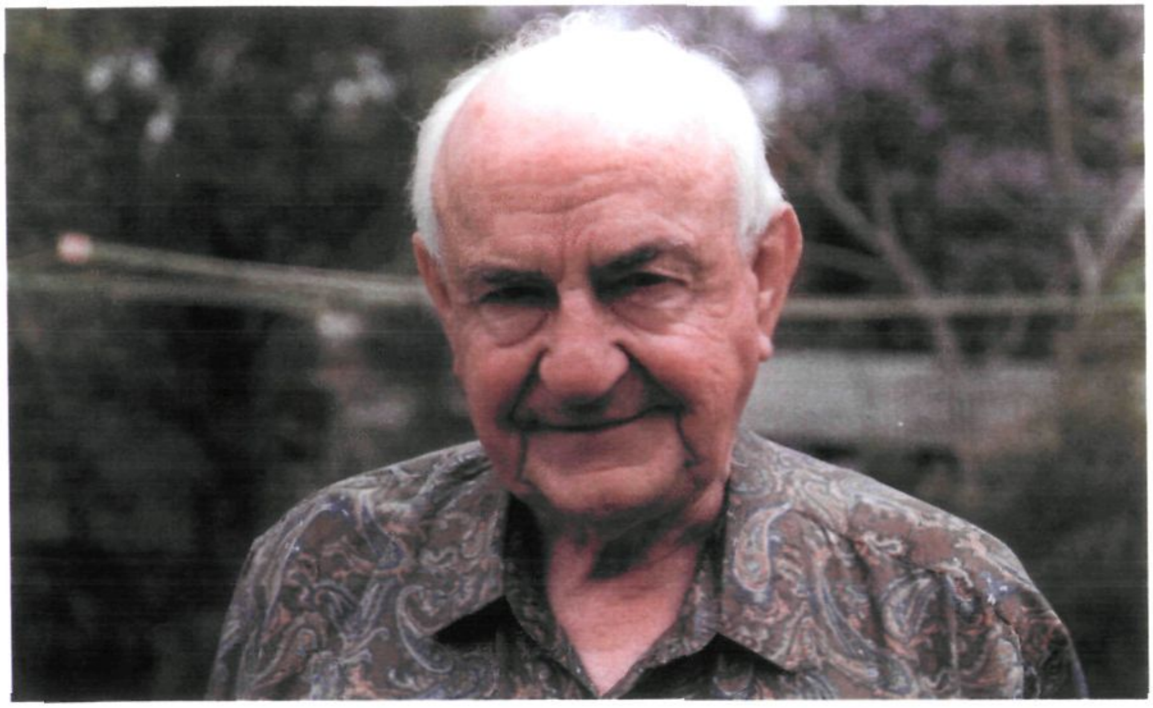


When it comes to stabilising and road construction equipment, Allan O'Meara knows all there is to know, having operated every piece of equipment that has been manufactured. He has also worked with every kind of material. He now works as Outdoor Supervisor for Pavement Salvage which has been in the profiling industry for twenty years and his work includes estimating, costing and allocating. Allan is also an expert on compaction and few men would know more about this subject. Allan is in great demand for his services.

Ken Porter

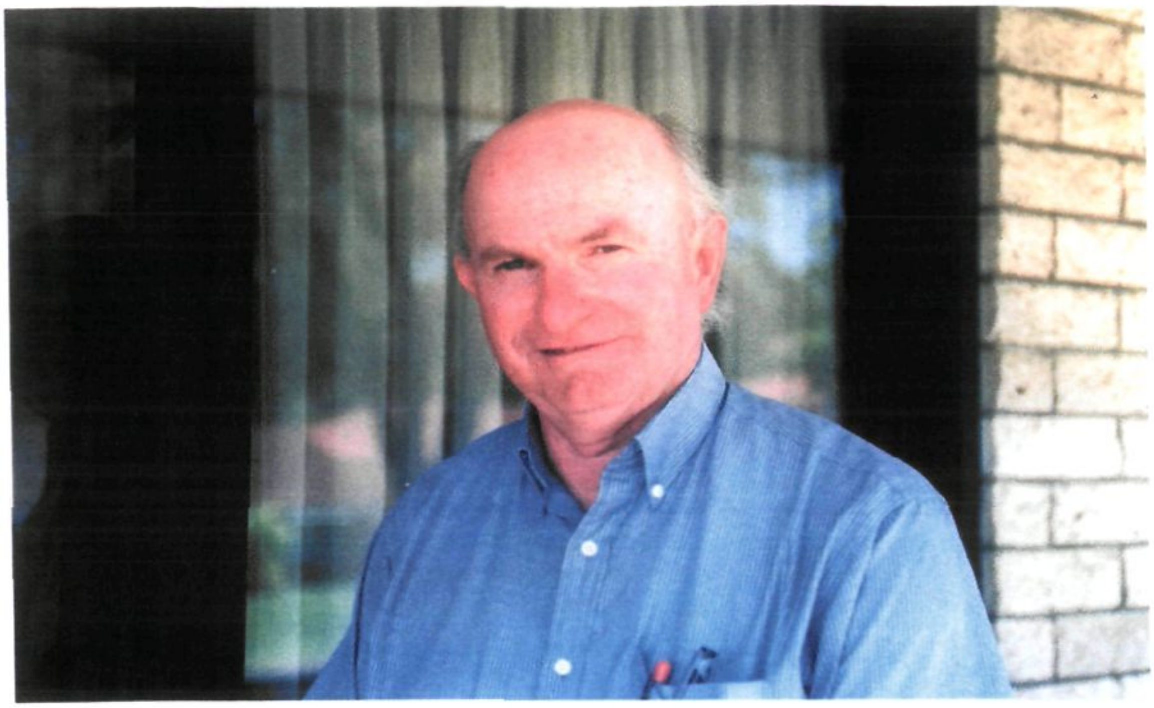
With a Master's degree in Civil Engineering and degrees in Geology and Geophysics, Ken Porter is well placed as Senior Project Manager, Private Infrastructure at RTA Head Office. He started his career with the DMR in 1969 as a trainee. He spent his first years with the DMR on the South Coast and Central Tablelands and has an exceptional knowledge of the processes involved in stabilisation and recycling. He played an important role in the success of the R&D and stabilisation trials across New South Wales and subsequent educational workshops held in the early 1990s which were crucial in determining the feasibility of deep-lift insitu stabilisation.

Doug Prosser



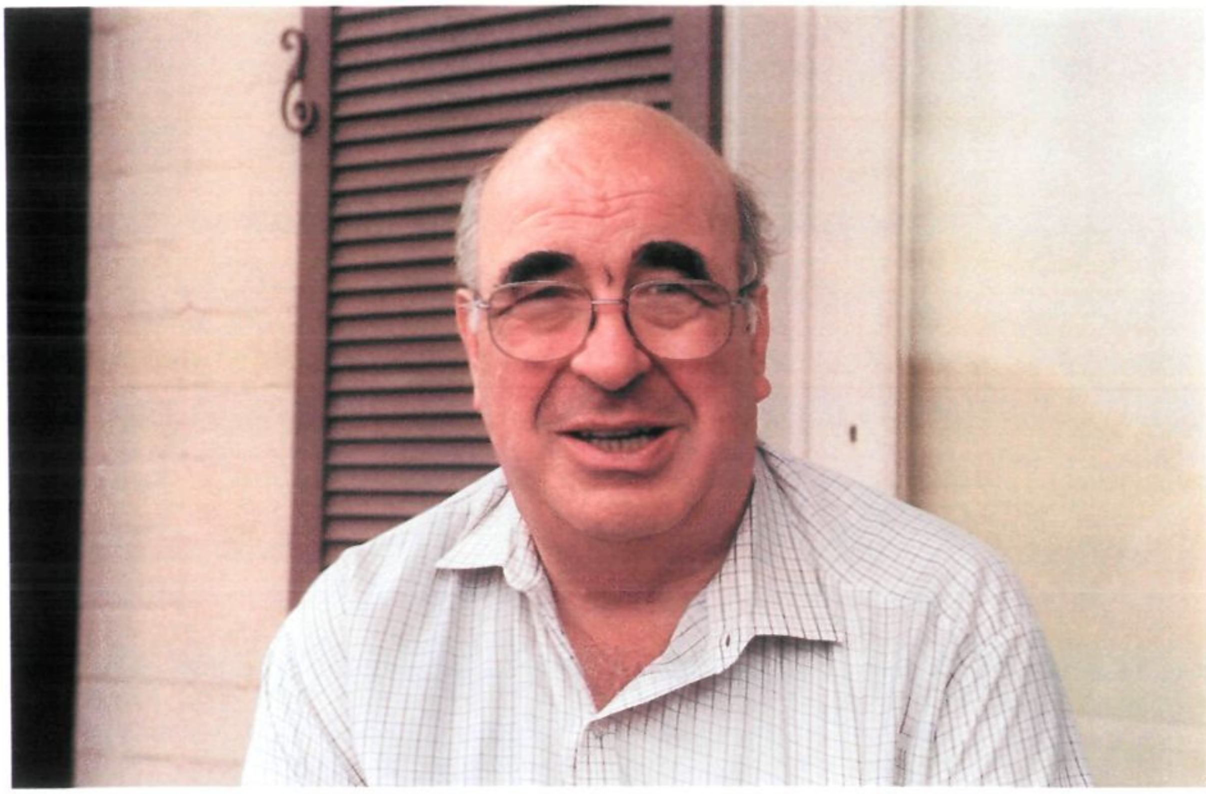
Born in Lithgow in 1925, Doug Prosser started work as an apprentice fitter and turner in 1939 at the Australian Iron and Steel works at Port Kembla. He became a draftsman for the company until setting up his own company in 1963. Since 1980, Doug has been involved with the sale and promotion of slag and basalt products for BMI Industries and he is now recognised as the undisputed 'father figure' of slag in Australia. A former Chairman of the Slag Association, the two and a half million tonne stockpile at Port Kembla was until recently, named 'Mt Prosser'.

Paul Ritchie



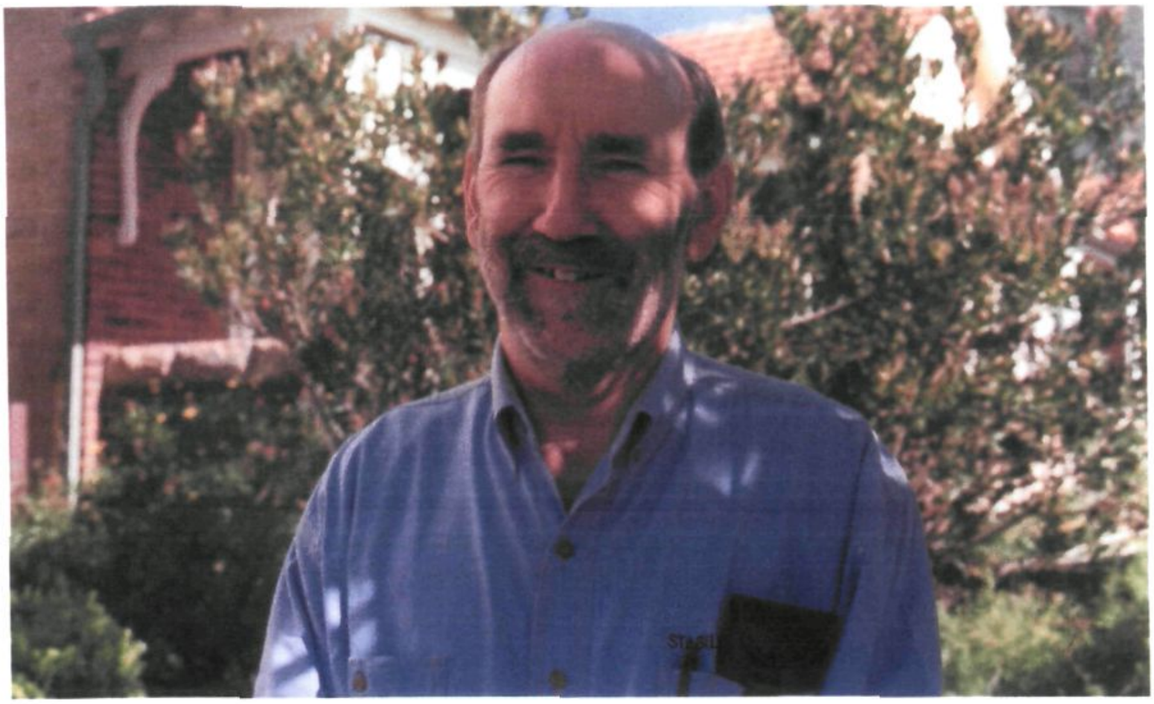
Paul Ritchie is a Local Government stabilisation pioneer. He joined Bankstown Council in Sydney's West at a time when it was embarking on a major stabilisation project to try to fix their failing road network. Ritchie not only proved that stabilisation worked and was more cost-effective than reconstruction, he also extended it to Blacktown and Holroyd councils from where it spread to Local Government around Australia. The work he carried out in Local Government in the 1970s firmly set the standards and foundation for stabilisation by Local Government throughout Australia.

Brian Shackel



Born in Portsmouth, UK, Professor Brian Shackel is an academic at the University of New South Wales. He studied Civil Engineering at Sheffield University and then left for Australia to join the DMR. He became Shire Engineer in Central Darling Shire, then recommenced his studies, obtaining a Master's degree. He became a teaching fellow and joined the academic staff at UNSW. He performed early important research work on foam stabilisation for Mobil Oil, developed software for stabilisation methods and tested South African pavements. Shackel built many stabilised pavements overseas, and one of his major projects was the construction of a coal terminal in Virginia, USA.

Warren Smith

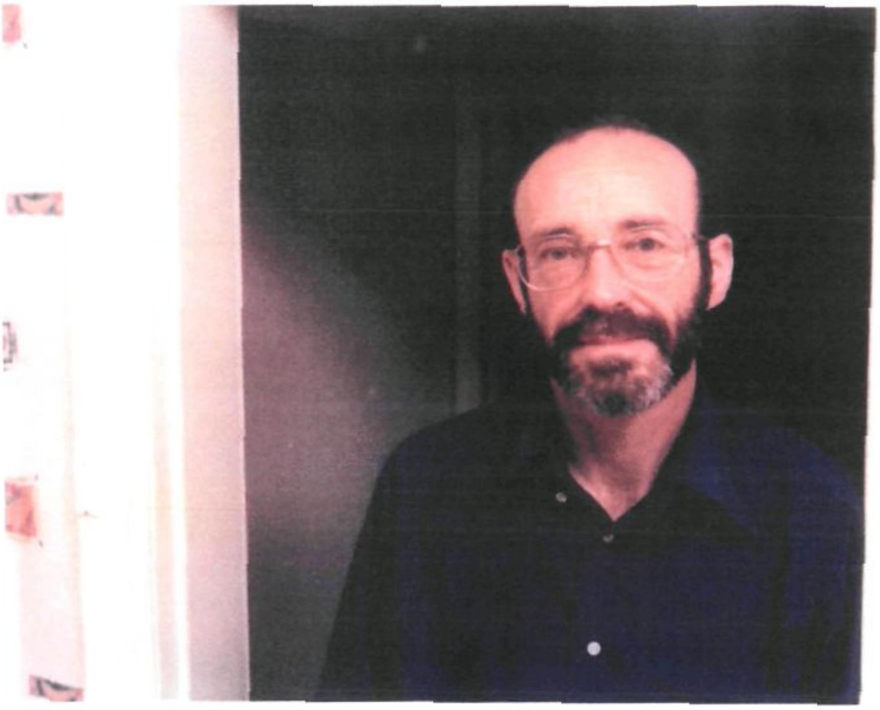


The founder of Stabilised Pavements of Australia (SPA), Warren Smith began stabilising Local Government roads using mainly pugmills. He and his partner then imported the large new reclaimers and they have been at the forefront of innovation and the use of new technology. He has had over 30 years of experience as a contractor in the pavement industry. Part of his job is to train Local Government and RTA staff in the use of stabilisation. Warren is Vice President of the Australian Stabilisation Industry Association Ltd.

George Vorobieff

George Vorobieff is Director of Head to Head International and Executive Director of AustStab (Australian Stabilisation Industry Association Ltd). With over 20 years of engineering experience, he has published over 100 technical papers. He has experience in the design and specification of flexible and concrete pavements and recently produced a manual for the concrete paving industry. George is convener for a project examining the characterisation of stabilised materials using lime, cement and bituminous binders for road stabilisation. He is also a member of the Austroads Pavement Reference Group. His qualifications include an MBA from Macquarie University, a Master of Engineering Science (UNSW) and Honours in Bachelor of Civil Engineering (UNSW).

Phil Walter

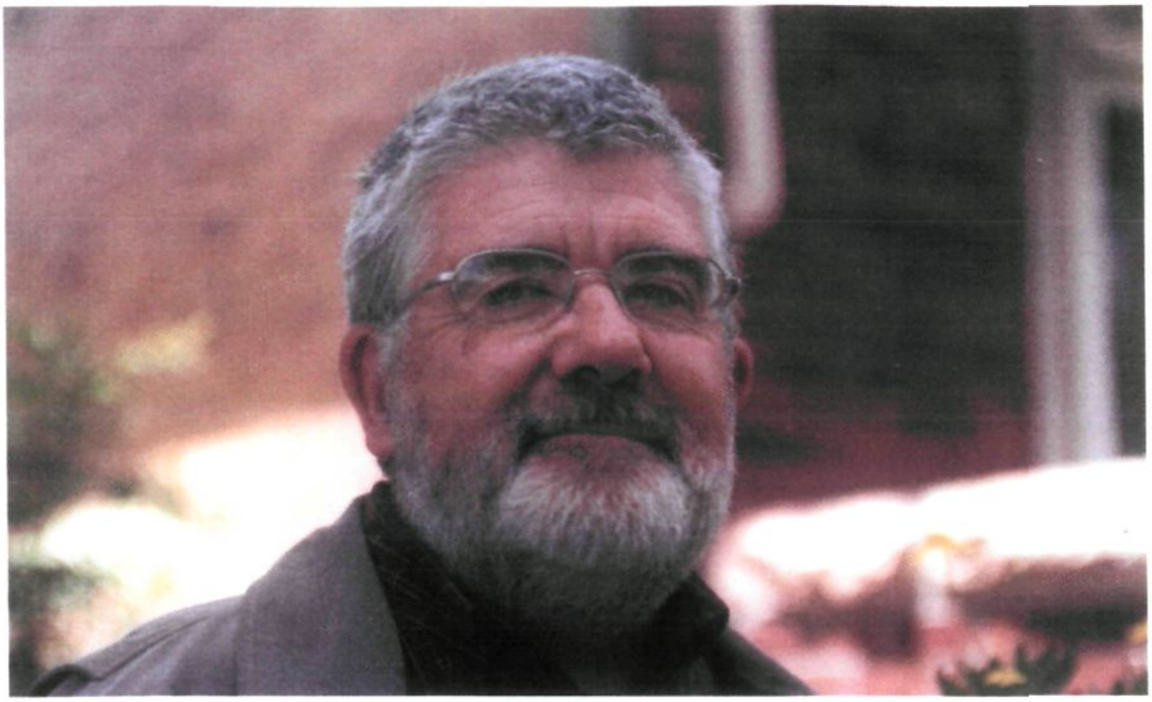


Phil Walter was awarded a scholarship by the DMR to study Civil Engineering at the University of Sydney and then obtained a Master in Engineering Science from the University of New South Wales. One of his first tasks at the DMR was the reconstruction of the Oxley Highway. He then advanced to the Materials and Research section under Alan Leask, who introduced Mechanistic pavement design procedures. He was involved with the first black soil stabilisation project and deep-lift insitu stabilisation activities at the RTA. Phil has an extensive knowledge of stabilisation procedures and is Manager, Flexible Pavements in the RTA Pavements Branch.

Tom Wilmot

A former President of the Australian Stabilisation Industry Association Ltd, Tom Wilmot has more than 30 years of experience in the pavement industry. He began his stabilisation work using foam stabilisation equipment and stabilised the shoulders of the runways at Tullamarine jetport. In the 1970s and 1980s, he worked closely with engineer Paul Ritchie and as contractor, stabilised most of the roads for Bankstown and other Western Sydney councils. He was instrumental in bringing the first CMI RS-500 reclaimer into Australia and is a Director of Stabilised Pavements of Australia Pty Ltd. His activities have spread beyond Australia with large stabilisation contracts in the UK and Asia.

Geoff Youdale



Now a consultant, Geoff Youdale has spent most of his working life at the DMR and RTA. After completing a Master of Engineering Science at the University of New South Wales, he took up research work in the DMR's Materials and Research Laboratory into pavement materials. He tested materials for their elastic properties and built a machine to produce foamed bitumen in the laboratory. Youdale's most important contribution to stabilisation was setting up the pivotal R&D and ALF Trials in the 1990s, which proved the effectiveness of stabilisation and set the specifications. He became General Manager, Research and Development Strategy at RTA and is a past Chairman of the Austroads Pavement Research Group.