R T A

Better Roads. Safer Roads.
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Wollongong Technology Transfer Workshop

Wollongong, 2 & 3 May 1995

Proceedings

Technology Strategy Branch

ISBN: 0 7310 3639 5

CRB: 95.056

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Electronic Data Location System

by

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RTA Technology

1. SYNOPSIS

This paper describes an efficient, user-friendly system of electronic data collection for road and traffic asset inventory, location , survey and condition inspections, and maintenance activities. It is based upon rugged hand-held computers and minimum assumed computer competence in field crews, replacing unwieldy and costly paper-based systems. Extensive use is made of pen-free, flexibly programmed data entry screens tailored for each step of each application, of inbuilt data verification, and latest techniques such as GPS location and ROADLOC correlation.

2. BACKGROUND

The Authority is responsible for many thousands of kilometres of roads throughout NSW, and for associated assets such as centre lines, fencing and the like, as well as a host of other traffic facilities. These assets must be recorded for fiduciary reasons on behalf of the people of New South Wales. The number, location and condition of each must also be periodically inspected and recorded in order to ensure an adequate level of service, and assist in prudent maintenance of the assets to an acceptable standard.

Consequently the Authority is continuously reviewing its methods of collection of data to better achieve its objectives and fulfil its charter. To streamline the process the Authority has developed the ROADLOC system of unique identification for all sections of its roads in NSW, and a number of other system initiatives which are at the leading edge of asset management techniques around the world.

One such system is that of Electronic Data Location System (EDLS), with the following advantages:

- Field data may be collected more economically than by other manual, paper-based methods, with greater accuracy of data
- With operator aids-e.g., accurate position information, calculations, data verification,
- Elimination of unnecessary redundancy of inputting data in the field,

and more importantly,

- The elimination of the manual keyboarding of the field data into the office database.

3. WHAT IS EDLS?

EDLS a modular system concept which allows - through electronic data capture and transfer - the collection, validation, recording, issuing, location and transfer of field information. Modules are mainly software, resident in the hand-held computer, with special associated hardware where required (e.g., LOCATE, where accurate location information is obtained in conjunction with a GPS receiver and simple antenna.)

Modules comprise a rugged hand-held computer with touch-sensitive screen overlaid on a liquid crystal display, a number of data management and communication facilities e.g.,:

- EDLS Manager
- Data Communications Facility (DCF)
- Applications programs, such as
  Daily Running Sheets (DRS) for Maintenance Management System (MMS), ROCOND
  Road condition inspection system
  LOCATE system, using (Global Positioning System) GPS techniques for accurate location of projects/ work performed.

3.1 Hand-held Data Logger (Touch-PC)

All of the applications to date use the ACS Touch PC, a hand-held 286-based computer which is particularly rugged in construction, and chosen from a large range of available devices for its compactness, ease of data entry, environmental protection to 1PG 65, large memory and good battery life for extended field surveys.

Relatively light in weight (1 Kg), with 2M byte CMOS memory, the Touch-PC sits well in the hand, has no external keys of any kind, and is easy to use - an attribute which is appreciated by field gangers and supervisors alike, where computer literacy is not assumed..

Memory capacity, processing speed, battery life and lack of complexity of the Touch-PC have rendered it the preferred device for most data logging applications to date.

Long operational battery life between charges is achieved by low-power CMOS circuitry and memory, and by use of liquid crystal display screen. Data entry is achieved by a series of calling screens and secondary data entry screens which lead the operator through the particular process of the application. Screen design is very flexible is tailored to each application and suitable for the particular measurement or observation being made at the time.

It should be noted that the Touch-PC has a data protection facility where stored data is protected by a separate battery system from the main battery which powers the computer and screen.

3.2 EDLS Manager

The EDLS Manager module forms a gateway between the TOUCH-PC and the application database. It is common to all applications and resides on the office database (MMS, ROCOND etc) and the remote Touch-PC, and provides a standardised means of option selection for each application. It decides what data is extracted from the TOUCH-PC, and what is to be done with it. Set-up for a particular application is achieved by operator configuration on screen using menu selection.

3.3 Data Communications Facility

The Data Communications Facility provides a common communications interface for all applications, whether for local connection to PC or remote connection via data modems. IT operates through EDLS Manager, and provides all "Handshaking" required to establish, maintain and close down a data communications session between the host PC and the Touch-PC. It provides the operator with on-screen indication of:-

- which file is currently being transferred,
- estimated time to transfer,
- time to go to completion, etc.

A comprehensive system of debug/ message monitoring allows for assistance with:

- detection of poor quality Telecom lines,
- bedding in new data modems,

and results may be filed for later analysis.

3.4 GPS LOCATE Module

The GPS LOCATE module uses the GPS (Global Positioning System)satellite constellation installed under the Navstar project by the US Department of Defence and gives positive location of a project or vehicle. It is generally used with a vehicle-mounted GPS antenna and GPS receiver card. GPS LOCATE involves tracking of at least 4 of the currently 21 installed GPS satellites circling the earth every 12 hours or so. These satellites radiate coded signals which are picked up and decoded by the GPS receiver. The latter computes the accurate position of the satellites (longitude, latitude, altitude and time) from receipt of satellite identification, timing and other signals from the satellite and by knowing the detailed orbital path of each satellite (broadcast to users). By use of time of arrival measurements, and a triangulation process between the calculations on the 4 satellites in view of the users antenna, the GPS user's position is accurately determined and continuously updated whilst in view of the satellites.

However, in the RTA context, the accurate latitude and longitude of the users position is of little use to a ganger or supervisor in the field, where location on a particular road and segment is a far more practical measure, and the LOCATE module was specifically developed for this purpose..

The LOCATE module translates the GPS latitude and longitude information into ROADLOC co-ordinates by matching against a previously plotted "Base Map" of road segments. The base map is edited from a series of GPS readings taken on the centre of the carriageways at approx 20 metre intervals. In order to reduce processing time and data storage requirements in the Touch-PC, a series of conceptual "boxes" are then computed using established rules, and insignificant points discarded. The result, then is a quick search for the user's position by establishing which box he is in. Result of the search will be the Road Name, Segment Number, and Local Description (e.g., Hume Highway, Segment 110, Memorial Drive)

4. CURRENT APPLICATIONS

4.1 ROCOND - Road Condition Surveys

The use of dataloggers for road condition surveys has now been established in several Zones and replicates the paper based ROCOND survey methodology, which rates road segments on condition of pavements, drainage, and shoulders. The system uses a subset of the EDLS system (Touch-PC and RRS Manager, direct connect)

Benefits of this approach have been to:-

- Reduce training costs
- Enforce compliance to procedure
- Increase data integrity
- Reduce costs of data collection and processing (savings of 25-40% have beenestimated by users, due largely to elimination of paper records and subsequent off-line data entry process.

4.2 MMS Daily Running Sheets (DRS)

Featuring all modules of EDLS (LOCATE GPS, Touch-PC, DCF, and EDLS Manager) this application allows the ganger or supervisor to accurately locate the work site, to provide work activity account numbers, and details of work completed.

The Touch-PC has been well accepted by gangers and supervisors, as being :-

- easy to use,
- more acceptable than filling out "masses of paperwork"
- offers benefits in positively identifying the work
- and does not require special pens which can get lost in the field.

4.3 Travel Time Surveys

This application uses GPS for vehicle positioning, Touch-PC for system setup and recording and EDLS Manager for data transfer. The application allows the measurement of travel times to study the effects of traffic engineering changes over time, or effects of perturbations in traffic due to special events, road construction, etc.

5. KEY BENEFITS OF EDLS

- **Eliminates double entry of Data.** The data is entered by the rater/supervisor/ganger at source, thereby eliminating the need for a later data entry process back at the office.

- **Eliminates Transcription Error.** (Since there is no Transcription - a previous source of potential significant error)

- **Higher level of data accuracy/integrity**. Data is checked for error at the point of entry.

- **Reduces need to return to base**. Survey results may be simply uploaded to base. At any rate the Touch-PC provides secure storage of data from a survey of more than a day's duration.

- **More appropriate for field data entry**. In many instances in road based surveys, weather and environment conditions are not always ideal. For example, Slope surveys using A3 clipboards in days of high winds, rain and dust or mud. The Touch-PC is dust and water sealed to the appropriate degree for these conditions.

6. Applications in Development.

Currently in EDLS development are:

- **Traffic Facilities Management Survey and Routine Inspection Modules**

  Using an icon-based data input process on the touch screen of a hand held computer, standard traffic facilities (traffic signs, barrier strips, pedestrian crossings and several other items and zones) will be surveyed and routinely inspected.

- **Bridge Inspection System**

  Replicating the paper-based BIS methodology , the system will use the Touch-PC and EDLS Manager modules, and will provide a far more appropriate and cost effective means of collecting data on bridge elements and condition.

- **ROCOND Local**

  Replicating the methodology of the existing paper based ROCOND LOCAL system - the local Government version of the RTA ROCOND system, the project will allow a more appropriate and cost effective data collection method than previously, and allow some synergy with other RTA systems in LGA's.

7. PROPOSED APPLICATIONS

- Work Request Module
- Wages Timesheets
- MMS Data Collection
- RIS Data Collection
- Slope Surveys

Electronic Warning at Road Construction Zones

by

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1. INTRODUCTION

The visual appearance of our road system is gradually changing as Traffic Engineers resort to the wonders of IVHS to provide safer roads, reduced congestion and reduced travel times.

To achieve these benefits most systems rely upon conveying a specific message to motorists in order to cause a specific desired change in their behaviour. In a world where competition for visual attention (particularly by advertisers) is greater then ever it is natural that fibre optic Variable Message Signs (VMS) are relied upon to convey messages in these systems.

An indication of the diversity of the applications for which VMS is used in a study of European signs (Cummings 1994) is shown in Table 1.

VMS Strategy	Proportion of Sample	VMS Strategy	Proportion of Sample
Queue & Congestion	12.75	Merging control	3.0%
Incidents	11.9%	Tidal flow	3.0%
Weather information	11.2%	Special use lane	0.7%
Tunnel and bridge	3.0%	Traffic information	9.0%
Speed limits	9.0%	Access information	6.0%
Overtaking restrictions	1.5%	Route guidance	7.5%
Safety (in context)	3.0%	Parking Guidance	1.5%
Safety (no context)	3.0%	Environmental warning	0.7%
Warning of roadworks	13.4%		

TABLE 1 VMS STRATEGIES

Although some aspects of VMS signs (e.g. access to power, cost) still present problems with their use, the level of perspecuity available makes them ideal for use in a situation where it is critical to ensure a motorist sees a particular message at a particular point in time.

However it is this very ability of the signs to ensure they obtain a driver's attention which may lead to their inappropriate use. Disbenefits such as expenditure of funds on signs of little or no effect or signs where the distraction risk is greater than the accident risk being addressed need to be adequately identified.

2. BACKGROUND

The ability of signs to cause a change in driver behaviour has been the subject of many studies over the years. Whilst VMS (fibre optic signs and electronically operated) have been in use for over 20 years (the original F6 Driver Aid system was installed in 1974), the outcomes on the effectiveness of such signs are only now becoming studied in detail.
A scheme operating in Melbourne from 1987-1990 which advised drivers of speeds to travel to let them arrive at traffic signals during the green phase was unsuccessful (Jakovic 1991). The system was considered a failure because "drivers chose not to drive at the advised speed limit.....a review of the system found no significant energy savings or reduction in the number of stops or accidents".

More recent work has been done on trials to modify route selection by motorists have been undertaken in Paris as part of the SIRIUS program (Durand-Raucher et al 1993). Over 200 remotely controlled fibre-optic signs gave real time traffic information to motorists. Studies indicate 3 % to 5 % of the traffic flow diverted when faced with comparative information regarding traffic congestion.

In the UK a fibre optic display was attached to a digital character recognition system which allowed a speed to be displayed together with the license plate number of the offending vehicle (Hill 1995). At a stage where the information displayed was only advisory a reduction in the 85th percentile from 90 km/h to 82 km/h was achieved in a 80 km/h work zone. The system is now being developed as a full speed enforcement system with pictures of the display to be used as evidence of speed violations.

Similar trials in the US using VMS to address the problems of speeding traffic at roadworks (Garber and Patel 1995). These results confirm the effectiveness of VMS in reducing speeds and examine the results of using differing messages to achieve these effects.

3. RTA F6 TRIALS

As part of the F6 Driver Aid replacement system the RTA undertoook a research project to assess the effectiveness of available technology to provide a replacement for the fog warning system which was erected on the F6 Waterfall - Bulli Tollway in 1974. (Brisbane 1993).

The intent of the trial was to advise of motorists of fog conditions and appropriate travel speeds for those conditions. However advantage was taken of the system developed to advise drivers of when their speeds were in excess of the speed limit (100 km/h).

A range of messages were used utilising different speed 'trigger'points in advance of the sign. Analysis was carried out on the speed of vehicles throughout the 600 m of the test site due to the different variables including the effectiveness by time of day (Brisbane 1994).

The results for the most effective configuration are shown in Fig 2. These indicate a reduction in the 85th percentile from 112 to 106 is achievable (at 150 m past sign). However it is noticeable that there was an actual increase in speeds in the approach to the sign whilst any effect has effectively dissipated 500 m after the display was first visible to the driver.

This is consistant with two known facets of behaviour. Firstly the reward effect in that the only way to get a reward (ie turn the sign on) is to speed in the approach to the sign. Since this is a concious action motorists would be aware that they are speeding and still reduce their speed once the display is triggered.

The second aspect of note is that the effect dissipates by 500 m after the display first becomes visible to the driver . This supports the proposition that drivers adopt a behaviour they believe to be compatible with their immediate environment. Similar results were achieved in the US tests (Garber and Patel 1995) where the effect of the signs continued throughout the worksites but dissipated as the hazard ended.

In terms of the test site, any perceived threat requiring a change to behaviour as indicated by the sign display quickly passes as the motorist makes a reassessment of the environment. At a point 300 m past the sign (over 10 seconds in driving time) the change in behaviour caused by the sign has been replaced by a new behaviour based upon the road layout now facing the driver. With no change to this environment from the before situation, no basic change in speeds is shown between the before and after cases.

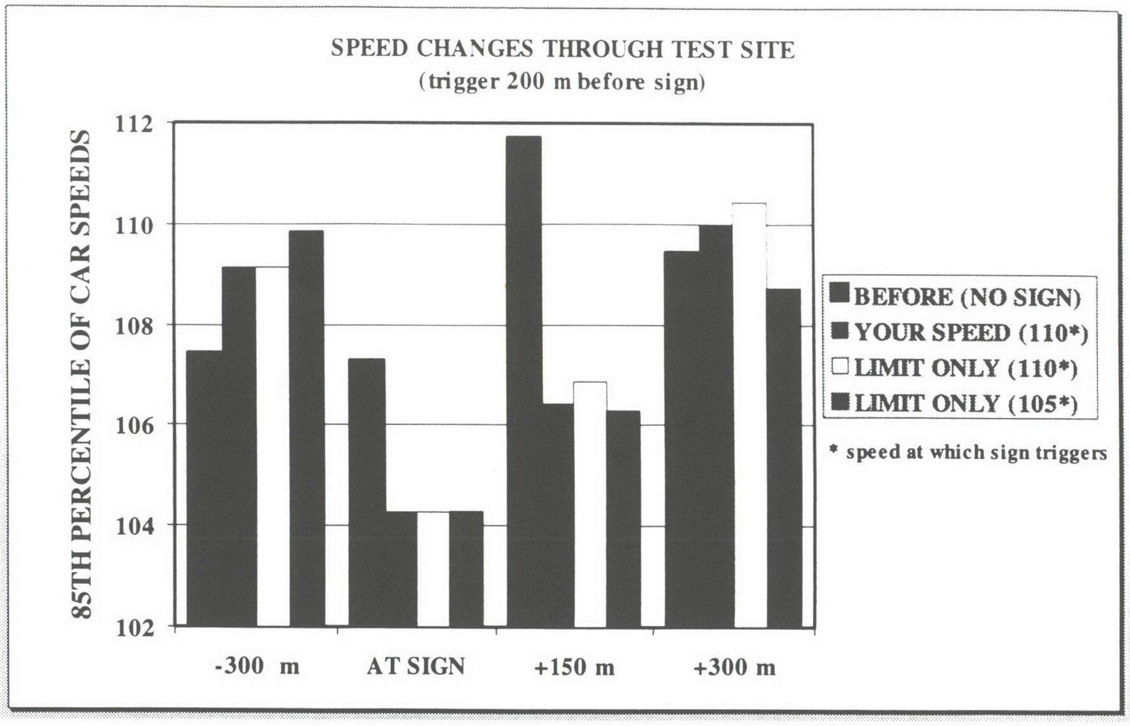

FIG 2: VARIATIONS TO 85TH PERCENTILES IN VARYING CONFIGURATIONS AND LOCATIONS

Following the results of the trial, a full replacement fog warning system is currently being put in place. The system is not yet fully operational and some difficulties have been experienced in reliability and in determining the accuracy of vehicle speeds, However advantage was taken of the system's capabilities to advise drivers when they were exceeding the speed limit by more than 10 km/h.

The results are mixed showing no changes of significance to 85th percentiles speeds or mean speeds in the fast lane but a reduction in the mean speed of around 10 km/h for traffic travelling in the slow lane. Again this could reflect the reward effect with a proportion of drivers speeding up trigger the signs whilst the majority of traffic react to the sign by slowing.

When the system is completed further work will be undertaken to assess the effectiveness of a range of display messages, particularly with respect to eliminating some of the reward aspects of the displays.

4. CURRENT PROJECT

It is obvious from the results to date that Variable Message Signs do have an effect on drivers. However this effect varies considerably. The best effects appear to be when the message displayed is supported by the need to make a decision. Against this messages triggered by vehicles can result in undesirable behaviour to the detriment of the message's purpose.

In order to test the effectiveness of such signs a mobile trailer mounted VMS has been developed at the Authority's Rhodes Workshop. The sign uses a new type of fibre optic sign which utilises liquid crystal to cover the fibre optics. These can be made transparent or opaque to make the appropriate message display. This is expected to improve the reliability of the sign in comparison with those which rely on mechanical shutters to occlude the light.

The sign consists of three levels of six alphanumeric characters. Letter height is 200mm with the display being setup from a computer within the trailer.

To determine before and after speeds two Trafficorders have been adapted with radio communication for recording speeds on the central computer. The speeds at the before site also provides sign activation which needs to be placed to be visible from the activating vehicle.

Typical situations where the sign's effects are to be evaluated are roadwork sites, temporary road connections, blackspots and in association with police radar campaigns. Particular attention will be paid to the results of using different wording and the respective effect on traffic.

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Performance Specified Maintenance Contract

by

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Infrastructure Maintenance

1. INTRODUCTION

The Roads and Traffic Authority (RTA)(led by its Sydney Region) began its contract asset maintenance strategy in mid 1990. Since then the Region has established a highly successful term maintenance contract, and is now using that experience in the initiation of a comprehensive performance specified contract.

The contracting of road maintenance is in its infancy in Australia and overseas, and the Sydney approach has been internationally hailed as being at the "leading edge" of international practice. The performance specified approach will be the first comprehensive road maintenance contract of its type in the world, and will break new ground in the specification and measurement of road performance.

This paper describes the approach taken by the RTA to the integration of the performance specification concept with road maintenance contracting initiatives. The paper highlights results, key issues and future options.

The paper also stresses the benefits flowing from the formation of an interdisciplinary approach from the earliest stages of contract development.

2. WHY DO WE CONTRACT?

All organisations in today's economic climate experience the pressure to provide service more efficiently and effectively. Public infrastructure agencies also face the challenge of protecting the community's investment in a considerable public asset whilst continuing to provide a level of service consistent with the community's increasing expectations. Decreasing funding, aging assets, and competition with other community services highlight the need to be able to do more with less.

In both the private and public sectors, traditional monopoly organisations are choosing to concentrate on being the "owner" and "buyer" of goods and services rather than the "provider", thereby increasing flexibility and reducing their long term costs.

The separation of accountability for service definition (the owner and buyer) from that of service delivery (the provider) overcomes the traditional conflict of interest between optimum asset management and necessary resource management. Road maintenance is a good example of this conflict. Most public sector road agencies are accountable for the management of public funds and assets and also for the utilisation of resources employed by the public purse. Management may find conflict in programming funds to activities which give optimum road asset performance where such a strategy may under-utilise dedicated physical resources. Since optimum resource management does not guarantee optimum asset management, the separation of the buyer and provider roles ensures that programming decisions are based purely on the needs of the asset.

Other reasons why it may be advantageous to contract, particularly on a performance specified basis, include:-

- Reduced costs through competition
- Enabling the organisation to channel savings to other services, or to improve the level of service
- Improved service delivery through clearer definition of service specifications, activity objectives, obligations of parties, quality and scope of activities, and subsequent monitoring and enforcement
- Flexibility by freeing program from resource and budgetary constraints
- Encouragement of contractor's flexibility, innovation and the application of new, improved procedures by specification of product, not method

- Identification and equitable allocation of risks between the buyer and the provider.

Contracting, of course, does not detract from the need to ensure quality, workplace safety, equity or probity in business processes.

Evidence available from contracting initiatives in the public and private sectors in Australia and overseas suggests that the average reduction in cost through the introduction of competition in the delivery of a product or service is in the order of 20%. The 1991 Industry Commission paper estimated that the resultant efficiency gain across all levels of Government in Australia is approximately $4.5B per year.

Australian Governments have also given a strong indication of their intention to increase the amount of public sector work placed under contract, as a part of their micro-economic reform packages. Examples of this are advice from the Federal Department of Transport that road agencies will be required to contract maintenance works directly funded from federal sources, and the launching in April this year of the NSW State Government's policy statement for Contracting Out and Market Testing to ensure that service delivery is achieved in the most cost-effective manner.

3. THE SYDNEY REGION PROJECT

The Sydney Region is 1 of 4 Regions of the RTA and is accountable for the management of a network of over 1,600 kilometres of urban road, involving over 7,000 kilometres of traffic lane. A map of the Region, showing the management zones used for maintenance purposes is attached as Attachment A.

The Region's annual maintenance program is in the order of $110 million, of which approximately $80 million is available for maintenance of its road assets. In addition to its road pavements, the Region's non-pavement assets are substantial, and include more than:

- 700 bridges (including the Sydney Harbour Bridge)
- 2,500 sets of traffic signals
- 175,000 traffic signs
- 800,000 square metres of road markings.

Prior to 1991, the Region's roads were maintained by a combination of RTA and local council workforces, supplemented by specialist sub-contractors. The management approach was traditional, with budgets allocated to Works Offices, or Councils, who were responsible for the preparation of "Maintenance and Improvement" programs which included routine maintenance, specific preventative maintenance works, minor network improvement works and bids for more substantial replacement or restoration works. The Works Offices were then responsible for network inspection, defect prioritisation and work delivery. In this fashion, accountability for both network planning (owner) and resource management (provider) were vested in the one manager.

In 1990 the Sydney Region commenced the development of a comprehensive road maintenance contract, which was the RTA's formal contract maintenance pilot.

The concept of a performance contract in the first instance was considered, however, it was felt that, given the dearth of private sector expertise in road maintenance, it was necessary to minimise risk exposure to both parties by the adoption of a more conventional style of contract. The conventional approach also gave the RTA more control over the day-to-day activities of the contractor and this was of comfort to the RTA during the trialing phase.

At the time when the pilot contract was let, road maintenance was essentially a government monopoly, the private sector having little involvement other than as an activity, or job, contractor. In consultation with industry it was agreed that the initial contract would be designed to nurture the necessary skills and understanding within both the RTA and industry.

The development of the contract commenced with an internationally advertised invitation for expressions of interest for the provision of assistance. This allowed the RTA to canvass international practice, and take advantage of international experience.

A proposal from an Australian firm (CMPS&F) which had joined with experienced firms in the United Kingdom and Europe was selected.

The adopted contract approach was based on UK Department of Transport practice for the maintenance of major motorways in that country. The general approach was modified to suit road conditions in the pilot areas, Australian contractual procedures and Australian management practices and quality regimes.

4. THE CONTRACTS

The RTA pilot comprised 2 contracts with the private sector and, for the purposes of comparison and evaluation, a "contract agreement" with the RTA workforce entity responsible for the network prior to the pilot. The 2 private sector contracts were:

(a) Maintenance management contract

A contract for the provision of maintenance management services, including network inspection, defect prioritisation, work definition and direction, budget development and control, quality assurance of works, treatment design, and reporting.

This contract included a specifically designed "Code of Practice" as its technical specification, which defined the level of performance expected from the maintenance manager.

The initial contract was awarded for a 2 year term, and included 2 networks of approximately 100 kilometres of roads in western Sydney. The works delivery on one network was a private sector contractor (see [b] below) and on the other network was the RTA workforce. Identical documentation and management procedures were used on both networks.

(b) Maintenance delivery contract

A comprehensive Schedule of Rates contract for the provision of maintenance services, which involved the delivery of works as directed by the contracted maintenance manager in accordance with the time, cost and quality requirements specified in such direction.

The contract utilised standard construction contract conditions and specifications, which were heavily modified to make them appropriate to a maintenance contract. The contract was a Quality Assurance contract.

After tender, the initial contract was awarded for a 2 year term, and included a network of approximately 100 kilometres of roads in the Liverpool area of south-west Sydney.

The following points should be noted with respect to the 2 contracts:

- Together, the 2 contracts constituted a form of "performance contract" where the product was identified by the performance parameters defined in the maintenance manager's Code of Practice. However, the RTA's retention of budgetary control limited the latitude of the contractor in this instance.

- The style of maintenance services contract allowed for a detailed evaluation of the comparative costs and productivity of the contractor with the RTA. Such an evaluation is difficult with a performance specified style of contract.

- The contracts were designed to assign risks to the appropriate elements of the private sector. Generally, contractors are accustomed to minimum risk exposure because of the degree of work definition usually provided. On the other hand, consultants are generally accustomed to lesser defined tasks and a level of risk consistent with their professional responsibility. Hence, it was logical in this instance to separate the task into 2 contracts and allocate them across the industry in this fashion.

5. THE RESULTS

The results of the pilot were impressive and beyond initial expectations.

A detailed evaluation of the contract over its initial twelve months found that:

- The contractor demonstrated an ability to respond to all emergency situations which arose, including accidents and a prolonged flood and storm emergency. The contractor's emergency response capability completely satisfied the requirements of the police and emergency services.

- There was no identified or demonstrated difference in the quality of the work undertaken by the contractor and the RTA.

- The maintenance manager quickly adopted network management processes, and procedures, that were equal to, or in some cases superior to, those traditionally used by the RTA.

- At the commencement of the contract term the contractor's average costs were measured at 16% less than those of the RTA's workforce operating under similar operating conditions.

- Over the first twelve months of the contract term the RTA's workforce achieved measured improvements in average productivity of 22%. This improvement was a direct result of the introduction of competition into the workplace.

- Over the term of the contract the condition of the assets and the level of service provided was maintained.

- As contractual work is initiated in response to road need, without consideration of resource utilisation constraints, the effectiveness of the distribution of the routine maintenance budget improved by an average 10%. This means that 10% more of the budget was able to be diverted to activities supporting the safety and structural outcomes of road maintenance than was possible in non-contract areas, where the need to utilise available resources led to the scheduling of a greater proportion of labour intensive environmental works than required by the needs of the network.

This result left no doubt as to the feasibility and effectiveness of road maintenance contracting, and led to the Sydney Region restructuring its entire organisation to take advantage of the gains in efficiency and effectiveness which resulted from the adoption of this new maintenance management philosophy, and to commence planning for a new generation of contract based on performance specification.

6. CURRENT PRACTICE

On the basis of the outstanding result achieved in the pilot, the extent of network under contract was increased in 1992. The maintenance services contract in the Liverpool zone was increased from 100 kilometres to 250 kilometres, and now covers the entire zone. The maintenance management contract was increased from 200 kilometres to 550 kilometres, and includes the entire Liverpool and Penrith zones.

The degree of private sector contracting in Sydney has not changed since 1992, however both the initial maintenance management and maintenance services contract terms expired in 1993, and the contracts retendered. The results of that retendering process were:

- Two firms were each awarded a separate contract for maintenance management for the Liverpool and Penrith zones, at a reduced average cost.

- The initial contractor was successful in the tender for maintenance services in the Liverpool zone. However the average rates tendered by 5 of the 6 tenderers were below the average rates in the initial contract, with the average rates of the lowest tenderer being approximately 25% below the initial contract average rates.

Therefore, the average rates of maintenance services by the private sector contractor are now a total of 41% below the rates being delivered by the workforce prior to the commencement of contracting. When the 10% effectiveness gain resulting from the resource flexibility effect is included in this result, the move to contracting road maintenance has increased the cost-effectiveness of maintenance in the contracted zone by more than 50% over 2 years, an impressive result.

Prior to the second round of tendering, the Region took the opportunity to revisit the contract documentation, and incorporate lessons learned in the first round. For the maintenance services contract, this involved the drafting of a totally project specific Conditions of Contract, as distinct from the adaptation of construction documentation used in the initial contract. The maintenance management contracts were also redrafted and simplified. This new documentation has significantly simplified the contracts and hence their interpretation and management. This involved close liaison between the Region's technical staff and the RTA's contract legal experts.

In 1992 a major restructure of the management of the Sydney Region was undertaken. That restructure utilised the findings of the pilot study by adopting the contract management approach in the Region's structure. The result was a 3 tier structure as summarised in Attachment B. The model has a clear separation of accountability for the different and often conflicting roles of planning (owner), network maintenance management (project manager), and resource management (builder). This has meant a shift in management philosophy from one where resource management was a key driving factor to one where the needs of the assets are the primary factor. As indicated by the diagram the RTA's maintenance management staff and maintenance services staff are equivalent to, and compete with, private sector contractors. Thus the RTA's direct control workforce is now dependent upon separate maintenance managers for their flow of work, and the maintenance managers are able to schedule and direct work free from resource utilisation constraints, exactly as the private sector contractor is dependent on the maintenance manager.

Consistent with the findings of the contract pilot, the new structure resulted in an improvement in the effectiveness of the distribution of the routine maintenance budget.

The measured trends in average unit rates for road maintenance works since the commencement of the contracting pilot in July 1991 are set out in Attachment C. The key information from that chart is:

- The average cost of works by the RTA's workforce has decreased by 19%.
- The average cost of work by the private sector contractor is currently 41% of the cost of that work by the RTA prior to the commencement of the contract.
- The Region's total road maintenance cost, weighted by the relative performance of the various groups, is 27% less than the total cost prior to the introduction of contracting.

7. The Next Generation Contract : Performance Specification

As indicated previously, the 2 contracts (maintenance management and maintenance services) developed in the contracting pilot were chosen to minimise the risk exposure of both the RTA and the private sector whilst both parties established new skills and an understanding of the issues and risks involved.

Following the success of the pilot, the continued reduction in the cost of work, and the improved understanding of the task by industry, the Region has elected to further expand its extent of contracted road maintenance, using a performance specification form of contract (also known as a "service level agreement", "benchmarking contract" or "end product contract"). This is a significant shift from previous contracts as it will be specified by the condition of the road assets over the term of the contract and not work, budgets or tasks.

The stated objectives of the new contract are :

- to improve the condition of the road assets and/or reduce the total recurrent maintenance cost against an agreed benchmark based on current RTA practice and funding
- to enhance and develop skills within the road industry which enable effective management and delivery of road asset maintenance
- to equitably allocate road maintenance risks between the RTA and contractor
- to develop and implement a simple, effective contract that is both precise and manageable, and is consistent with the principles of partnering between the RTA and contractor
- to promote and encourage the development and application of innovative road maintenance practice.

The benefits of the performance specified model for road maintenance is that it includes the potential for improved roads at reduced cost, reduction in management and administration costs, sharing of risks with the private sector and the potential for the application of innovative approaches to funding, maintenance technology, materials and procedures.

When fully implemented, the contract will involve an agreement between the 2 parties surrounding the delivery of an agreed service level, measured in terms of the condition of the road assets, for an agreed remuneration schedule. Essentially, it is a lump sum style of contract, with the contractor and RTA sharing the many risks inherent in the road maintenance task.

8. Establishment of the First Contract

As with any new, innovative, procedure the establishment of the first contract will be the most difficult. The RTA and the private sector will need to jointly define the nature of the agreement itself, the scope, the risks and the information requirements.

Following the assessment of concept proposals from the private sector, 4 proponents were shortlisted to proceed with detailed studies and the preparation of a commercial contract proposal. Care was taken to not overly limit the latitude given to any proponent, concentrating only on the establishment of a robust evaluation procedure and the development of minimum mandatory requirements.

All proponents were provided with all available current and historical data relating to the roads to be contracted, relevant RTA manuals and documents, and were given access to RTA staff and facilities as required to gain an understanding of the asset maintenance task.

The contract proposals submitted by the four proponents were evaluated by an evaluation panel, including an independent "probity auditor", in terms of predefined criteria, which included:

- Commercial benefit to the RTA, Community and Government.
- Asset preservation, safety and environmental performance.
- Responsiveness and incident management.
- Technical advantages.
- Potential for resource transfer.
- Financial and technical capability.

The RTA has now selected one proponent to proceed with detailed negotiations and the joint development of the contract. The preferred proposal provides for a significant gain in road conditions at a cost well below that of the RTA. All other project objectives were achieved.

The contract is due for commencement in mid 1995, and includes the maintenance of all road, bridge, and traffic devices on 450 kilometres of road in the Sydney urban area. The term of the contract will be 10 years.

9. PERFORMANCE AND SERVICE LEVELS

Obviously, the key to any performance specified contract is the definition, specification and measurement of the service being delivered, its performance.

The road asset is comprised of many elements, each contributing to the function of the road, and hence the maintenance program outcomes. A relationship between elements and outcomes, can be established, viz,

Outcome	Examples of Elements
Structural	pavement, bridges, drains
Safety	signs, lines, shoulders, guardfence
Environmental	landscaping, siltation traps
Operational	traffic signals, guidance systems

This makes it possible to establish a relationship between the condition of these elements and maintenance program outcomes, hence, the service level provided. Also, since maintenance performance is an amalgamation of the condition of contributing elements an explicit linkage can be established between maintenance planning, management and performance reporting.

10. INFRASTRUCTURE FOR MEASUREMENT

Having established that performance and service levels can be measured in terms of the condition of the contributing asset elements, attention must turn to the means of measuring that condition.

Any performance measurement system must aim to be objective, repeatable, representative, and accurate. This is particularly true in the performance contract situation, as it is the measurement of performance which will specify the agreement and be used as the basis for payment, audit and measurement of contractor performance. Strong reliance has been placed on asset condition parameters which can be measured using proven automated technology. Some development of new systems is also necessary.

Fortunately, pavement condition surveys in Sydney using high speed laser technology were commenced in 1988. There is now a 6 year history of repeatable, accurate surface distress data available to assist in the development of the performance models necessary for this contract. Automated surveys to determine pavement structure (using radar technology), skid resistance and pavement deflection have been used to supplement this data. Combined with reflectivity monitoring devices for signs and lines, the measurement of condition for structural and safety elements can be almost totally achieved using automated devices. Some manual assessment is also necessary.

To complete the measurement package a statistical approach to define intervention levels and response standard is being developed. These condition outputs will also serve as performance measures for each program.

The strength in this approach lies in the fact that the same systems will be used by the contractor in his day to day operations management, thus ensuring the ongoing integrity of the system.

11. SETTING SERVICE LEVELS

A road maintenance contract is a particularly challenging concept, because the task is neither cyclic or predictable, and does not involve assets of known origin or future service potential. The Sydney road network is a complex structure with age, construction, and remaining life being difficult to pin down. Its behaviour is governed by the complex interaction of its natural materials, construction, temperature and rainfall patterns, time, and constantly changing traffic profiles. The challenge lies in the assignment of service levels that are economically viable and which protect the interests of the Government, the community and the contractor.

Earlier in this paper I indicated that commercial benefit and road condition were evaluation criteria used in the selection of the preferred contractor for the maintenance contract. Commercial benefit is concerned with the preservation of the community's investment in the road infrastructure, contractual payments, condition costs to road users, risk transfer, and ensuring that the community does not inherit a deferred maintenance liability at the end of the contract. Road condition is concerned with the provision of safe and functional road conditions at all times. Setting service levels is simply an adaptation of these criteria.

Service levels for a road maintenance contract evolve from the interaction of the 2 primary objectives, ie, commercial benefit and road condition.

In this first performance specified contract the RTA did not specify the service levels to be achieved by the contractor. The defined evaluation criteria allowed the proponents the latitude to consider innovative condition/funding relationships and to offer the RTA a performance/payment package in their contract proposals. Proponents took up this challenge, with the result that a variety of approaches, service levels and funding packages were received.

12. ALLOCATION OF RISK

Contracting is all about allocation of risk between the contracting parties. Under a conventional works or method specification, the contractor takes the risk on its performance (subject to external factors preventing performance, such as force majeure) and other risks are allocated by the contract. However, the conventional approach does not allow scope for transfer to the contractor of any of the risks associated with asset management, planning and prescription of method. The performance specified model, on the other hand, allows some of these risks to be transferred to the contractor.

Public agencies are accountable for the management of extensive portfolios of public assets, and hence for the management of risks associated with the ownership of those assets. Whether public road agencies make sufficient allocation for their risk exposure is debatable. For example, maintenance planners often use performance prediction models to forecast future trends and funding requirements, but pavement behaviour is a complex interaction of variables outside of the control of the road agency. A prolonged wet spell with extensive floods can be destructive.

A performance specification will allow agencies to transfer some of the risk exposure. The guiding principle is that risk should be borne by the party most able to influence or control it. Transfer of risk also means transfer of part of the traditional Government influence and control, but like any owner, the government retains the right of veto and direction where that is necessary to ensure that its obligations to the community are met The extent of any right of veto and direction will of course depend on factors such as the length of the contract and will be in addition to the right of government, like any contracting party, to insist on performance of the contract.

In the development of proposals for the performance specified road maintenance contract, each proponent examined the type, degree of exposure and potential cost of each of the risks involved. These included changes in weather patterns, increases in vehicles or truck axle loadings, floods, fires, and traffic accidents. Each of the contract proposals outlined the degree of risk accepted by the proponent and allowed for in the price.

The RTA also conducted its own analysis of the risks involved based on historical experience as ascertained from a risk management workshop. The workshop included staff who have traditionally been involved in road maintenance activities, and was also be attended by the RTA's lawyers and project team. The RTA also instructed its lawyers to review and advise on anticipated legal risks associated with the proposed contract.

13. A TECHNO-LEGAL (INTERDISCIPLINARY) APPROACH

Engineers are trained to think of contracts in very narrow terms. To most engineers, contracts are standard form documents under which a contractor agrees to construct a new asset for the principal or owner.

This narrow view may be a contributing factor to the reluctance displayed by many engineers to embrace maintenance contracting. Maintenance contracting requires a more flexible contracting approach than the construction contract approach which most engineers are familiar with.

One important aspect of the development of any engineering contract is the close involvement of both the engineering and legal professions. This is even more so in the case of a road maintenance contract, as road maintenance contracting is new to both the technical and legal professions, and both have a lot of thinking and learning to do.

In the case of the RTA's current proposed performance specified model, the establishment of an interdisciplinary partnership at an early stage is seen as a key to the success of the project. From a technical point of view, we already know how to do road maintenance: we've been doing it for as long as we've been road authorities. What makes the contracting model different is the contract itself and that has to be developed by the lawyers based on a full understanding of the technical requirements. If you wait until the last moment to instruct your lawyers to prepare the contract, you run the risk of being straight-jacketed by the contract because your instructions to the lawyers will be limited by your perception of what you think you want.

Both the legal and technical professions also benefit from the team-approach to learning about and devising contractual strategies for incorporating performance specification, which underlies the proposed concept. In addition, the funding aspects and lengthy term of the model currently being considered by RTA, require the expert input of both professions, to ensure that the technical aspects are incorporated in a contract document which allows and encourages flexibility, innovation and improvement over the term of the contract.

14. DEVELOPMENT OF A CONTRACTING STRATEGY

The preceding sections describe in some detail the Sydney Region approach to contracting road asset maintenance. It is not suggested, however, that this approach is the ideal approach, or is suitable for all road maintenance agencies. The Sydney approach was developed specifically for the environment in which the contract was to operate, defined in terms of network logistics, availability of a competitive contractor market, funding, and options for reallocation of existing resources. It is this "horses for courses" approach that is fundamental to the establishment of a successful contracting strategy.

Road agencies seeking to develop a road maintenance contracting strategy have several alternate contract options from which to choose, including :

*Specific Project Contracts - usually for works of a construction or rehabilitation nature
*Term, or Period, Contracts (either project-based, activity-based or network-based)
*Design, Build and Maintain Contracts - usually for works of a construction nature

For each of these options there are further options for the means of work specification. These range from the traditional prescriptive material and design specifications to the purely asset performance means of specification. It is suggested that each of the resultant matrix of options may be ideally suited to a particular case or agency, there being no "right" or "wrong" way. Indeed.

within any single road agency the best approach may be a mix of the candidate options, each ideally suited to given functions.

Road maintenance organisations currently have a choice as to whether they will embrace contracting, and if so, in what form(s), when, and to what extent. By acting on that choice now agencies will be able to control the change process and optimise the rewards that may result. There is evidence to suggest that the future adoption of contracting in the public sector may become a requirement, not a choice, and it appears that many agencies, or business units within agencies, will do little until such a requirement is entrenched. This strategy is fraught with danger.

Clearly, not all road maintenance organisations are the same, and what might be appropriate in one may not suit another. This applies equally to contracting approaches, management systems, application of technology, and a range of other variables. Within one organisation there may also exist sound reasons why a variety of approaches is ideal. To achieve the best long term result it is therefore critical that organisations carefully plan their contracting strategy, and not be caught in a position of being required to achieve an externally established goal. In the development of this plan organisations need to give consideration to the following issues:

15. MANAGEMENT

1. Any organisation changing from in-house delivery to contract delivery must also change its management philosophy, for the organisation will move from being a provider to a buyer. The natural progression for an organisation will be to de-emphasise the resource management function of its operation and reinforce the service definition and delivery functions. The focus of resource management will also change from management of internal resources to contract management.

   This is potentially the most critical step, as a lack of commitment to the new approach could result in failure, or the achievement of less than optimum results. Management must understand that its own flexibility may be reduced in a contractual environment.

2. Develop management procedures and systems to reflect the contracting strategy, and avoid the temptation to apply current systems designed for in-house operations to contractual management. Failure to do this will result in emulation of the current approach, and may stifle the success of the project.

   This is an important step in strategy development, and one that is often overlooked or underestimated. Most management systems are designed to reflect the processes and procedures used, and hence the management culture and philosophy of the organisation. The evidence shows that few of the management systems used in an in-house organisation survive this transition intact.

16. DEFINITION OF SERVICE

1. Define the maintenance services required or the performance parameters required to be met. This may seem obvious, but appears to be an area that has resulted in problems. Definition of agency requirements is a risk which cannot be divested by contract. The trap is, that in developing a contracting strategy the organisation may seek to emulate its current or past operation, thereby limiting the ability of the strategy to be flexible and innovative.

17. APPROPRIATE CONTRACTING APPROACH

1. Match the options for contract approach to the various situations, giving due regard to short and long term constraints. What works in one area, one activity, may be less suitable in your environment or situation.

   Consideration should be given to both the short and long term. There may be a case to apply one contract approach in the first instance in order to encourage the development of skills and to familiarise all parties with the risks involved. After nurturing this skill base, a longer term strategy can be adopted building on the increased level of comfort with the concept and providing for greater risk transfer and less extensive/day-to-day contract administration. However, the strategy adopted should also consider the objective of sustaining competition in the longer term. Certainly, care should be exercised to ensure that a government monopoly on the delivery of road asset maintenance is not replaced with a private sector monopoly.

Agencies need to be innovative, and develop contract solutions that are appropriate to their organisation and their objectives.

2. Form a close liaison between the technical and legal professions from the outset. Maintenance contracts are complex and, in the first instance, should be designed and drafted to suit the particular case. From the engineer's point of view, early involvement of the lawyers will ensure that the technical approach is feasible, is capable of being worked into a binding contract, and will reduce the potential for problems during the term of the contract. From the lawyer's point of view, being involved at an early stage means gaining a better understanding of the intended technical outputs of the contract and being able to develop a suitable contracting strategy with an emphasis on flexibility, more effective and efficient contract administration and a capacity to accommodate innovation and change over the life of the contract.

18. RISKS ASSOCIATED WITH THE CONTRACTED TASKS

1. Identify, evaluate and allocate the risks associated with the road maintenance task. This will form the basis of the contract eventually entered into.

2. Design contractor indemnity and insurance provisions to suit the style and detail of the contract approach(es) adopted. This will ensure that the agency is not exposed to undue additional risks by contracting.

19. STAFF

1. Establish a consultative program with affected staff to ensure a smooth transition between in-house operation and contracted operation. If possible, a workforce management plan should be prepared which addresses the impacts of proposals and options for staff management. The input of industrial relations experts should be sought at an early stage.

20. SUMMARY

Contracting of road maintenance is not the minefield that some will suggest, with most committed road agencies reporting significant short and long term benefits. The keys are the commitment of the organisation and the adoption of a flexible long term strategic view in the early stages of contract development.

This paper has stressed the need to tailor the contracting approach to the needs and environment of the road agency, and the benefits which may flow from a properly developed contracting strategy. The conclusion has been that the contract approach, at least in the first instance, should not be standardised, for this will only stifle development and innovation, which are fundamental to the success of any change. However, once you have a contract approach which works for you, you can begin to standardise, with concomitant benefits of efficiency and familiarity.

Road maintenance is, and will continue to be, a public sector agency accountability. By acting now agencies can maximise their ability to control that accountability.

Road Network Video Capture

by

Michael Stanojevic
RTA Technology

2.1.3 Video Data Capture

This involved the survey of field data captured on videotape and automatically linked to the odometer. An office post processing system was identified to view the tape and enter the required road inventory data items.

2.2 Selection of Video Data Capture

The video data capture system was selected for the following reasons;

2.2.1 Basic System was Available.

Through previous work in the Sydney Region the Parramatta Video Car was a proven unit and could form the basis of the pilot survey requested by Southern Region. Minor modifications were able to be carried out in the given timeframe.

2.2.2 Re-use of Survey Videos

The survey videotapes produced could provide a record of other items for future use. It is expected that the survey tape could be used initially to view all edgelines, while a different user may view the tape to review all speed zone signs on the surveyed road.

2.2.3 Video Capture Issue Identification

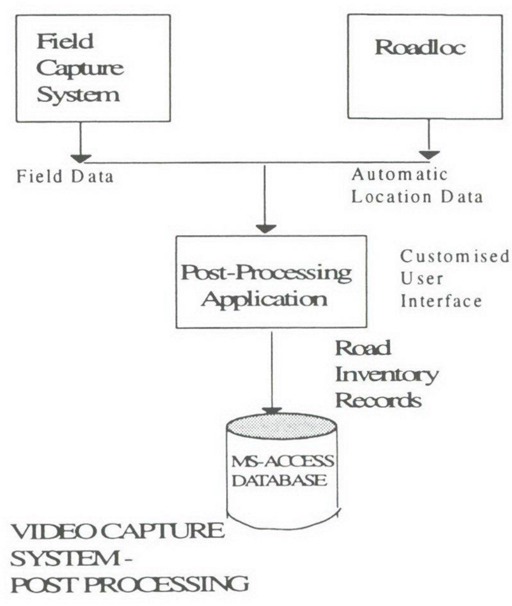
The system could be used to identify issues in the video concept that are applicable to usage in a broader environment.

2.3 Field System Schematic

The system used in the field is as follows. Note that the two main outputs from the system are the actual survey videotape, and the electronic data file which matches the odometer reading and time of the survey to the actual Roadloc location.

2.4 Office System Schematic

The system used in the office is as follows. Note that the data from the field survey is accepted into the post-processing system and used to validate the location of the entered Road Inventory data items.



2.5 Video Data Capture System Outputs

The outputs to the Video Data Capture System are as follows;

1. Survey Videotapes.
2. Road Inventory Database for uploading to the Road Inventory System (RIS).
3. A set of integrated queries designed to extract varied management information concerning road inventory items.

1 VIDEO DATA CAPTURE SYSTEM OVERVIEW

1.1 Introduction

This paper provides an overview of the Video Data Capture System being developed by the Technical Systems Branch. The system is being used to capture road inventory data using video tape recording of road networks and subsequent office data entry through MS Windows Graphical User Interface.

1.2 Objectives

The main objective in developing the Video Data Capture System is to satisfy identified user needs for the capture of large scale inventory data.
The secondary objective is to identify the issues involved with the use of the technology, and research possible resolutions.

1.3 Customer Requirements

The requirements of the customer is to provide an efficient means of capturing data over an extensive network. The system is required to be;

- Reliable by using current technology
- Flexible by being adjustable to specific user requirements
- Economical by limiting the amount of equipment and personnel required.
- Accurate in terms of the road inventory item detail and location.
- Safe by providing a safe operating environment for the personnel capturing the detail.
- Historical by establishing history of the road inventory and network for usage over time.

1.4 Current Development Status

The system has been developed in the following stages:-

1.4.1 Southern Region Pilot.

A pilot system was carried out in Southern Region to collect specific data over a wide network in a short timeframe. To videotape the required roads, this system used a special vehicle set up by Sydney Region, and based at Parramatta. An office post-processing system was specially developed by TSB in MS Access to enter the data captured on the videotape.

1.4.2 Proposed Generic System.

A proposed generic video data capture system is being developed to provide users with the ability to tailor their road inventory data capture to satisfy specific requirements. The office post processing system will allow dynamically tailored screens to facilitate the entry of data recorded on the videotape.

2 DETAILED DESCRIPTION OF SYSTEM

2.1 Initial Alternatives

There were three basic alternatives investigated before the video data capture service was selected.

2.1.1 Visual Survey - Paper Based Recording System

This involved manual linking of the odometer in the field with the road inventory items. The operator records the items with pen and paper as they are identified in the survey car.

2.1.2 Visual Survey - Electronic Data Capture

This involved items manually linked to the odometer in the field, but with input to an electronic device as sighted by survey car officers.

3 Benefits of Video Data Capture System

The identified benefits of the Video Data Capture System are as follows;
1. Re-use of Survey Tapes.
2. Safe Operating Environment
3. Fast Data Collection
4. Efficient and Accurate.
5. Cost Effective - limited resources required.
6. Fit for Purpose.
7. Reduced Field Inspection Requirement.
8. Super VHS Tapes allow good definition of inventory at high fast forward speeds.
9. All inventory items have ROADLOC location and time referencing.
10. Ability to split screens to record inventory according to user requirements.

4 PROPOSED SYSTEM

The proposed Video Data Capture System is designed to streamline the activities carried out by the Southern Region Pilot. An overview of the system is as follows:-

4.1 Hardware

The hardware involved in the proposed system is to be more refined in the sense that issues such as camera positioning, lens angles, car security etc are to be addressed. Issues will be investigated for the most cost effective solution.

4.2 Field Software

The field software will make usage of ROADLOC Tables for position location. The software will record the current location of the survey by accepting signals from the odometer and recording the data on an output file. The location data is also mixed with the videotape and appears on the survey picture screen.

4.3 Post Processing System

The Post Processing System is designed to accept the field data file and input survey videotape and facilitate the input of road inventory data items.
The benefits of the Post Processing System are;
1. Streamlined Linkage between Data and Tapes.
2. Generic User Setup
3. RIS Items Compatible.

Combined Girder and Deck Prefabricated Bridge Module

by

Tremayne West
RTA Technology

1. REASON FOR DEVELOPMENT

It is estimated that there are some 45,000 to 50,000 timber bridges throughout Australia with the majority located in rural areas forming strategic transport links between communities and essential services. Many of these structures are in need of urgent replacement or major rehabilitation. They are an asset which represent a nil establishment cost to us but possess a very large asset value.

It is well appreciated within the Engineering profession that one of the major problems presented to Road Authorities including Local Government Councils is the maintenance, rehabilitation and replacement of the timber bridge asset. Many of the bridges standing are still comprised of original timbers

Whilst the current low levels of maintenance expenditure exist the traditional methods of maintenance, comprising the replacement of members as required, have come under increasing scrutiny due to their high costs, resource restriction and inherent short life due to the original design and material deficiencies when unprotected. Traditional repairs are labour intensive and require large section sawn timbers which are increasingly difficult to source and present an environmentally “sensitive” material.

As such alternative rehabilitation techniques, of which this presentation highlights one, are being developed by the Roads and Traffic Authority of NSW to alleviate the problem of timber bridge repair and provide an engineered finished product of a permanent nature. Rehabilitation systems which allow the majority of the work to be carried out off site in controlled environments allow benefits to be realised in terms of efficiencies, quality, safety, reduced construction times and improved cost. In addition optimum solutions should provide a bridge with long life and minimum maintenance requirements.

2. HISTORY AND DETAILS OF THE MODULE

This presentation is centred on the current research and development associated with the application of the combined girder and deck prefabricated bridge module. The module system incorporates a girder system which is cast integral to the deck to form a prefabricated module. The girders can be steel or timber whilst the deck is reinforced concrete. The particular focus of the current research and development project is on the timber / concrete combined module.

The timber / concrete module presently utilises round hardwood timber girders of 450 mm diameter. The decision to use timber was based primarily on the cost advantage that it has over equivalent steel items as well as the consideration that timbers up to this size are in reasonable supply and are quickly replaced by regrowth as a renewable resource. In addition the application of round timber instead of the traditional use of large sawn sections overcomes the loss of up to 60% of the log during the milling procedures resulting in a higher yield and reduced unit costs.

It has been determined that precast modules with dimensions up to 3.6 metres wide and 12 metres long are required to satisfy the majority of applications. Such a module will weigh as much as 30 tonnes and is still readily transportable.

Initially the modules have been cast upside down with the timber girder supported above the slab formwork in T, double T, or triple T configuration. The timber girder terminates at each end of the module in a conrete diaphragm which provides bearing support and torsional stability. The timber pole is prepared by sawing a flat contact surface along one side with galvanised steel bolts and flat plates used as shear and tension connectors. As the timber will shrink up to as much as 10% across the grain due to moisture loss, the girder will not directly bear at the ends (figure 3). All bearing loads are transferred to the concrete slab by the shear and tension connection.

Drawings of a typical module are included as figures 1 and 2.

The timber / concrete module has an estimated cost of approximately \$300 - \$350 / m^2 with the steel / concrete module estimated at \$450 - \$500 / m^2 with a life anticipated up to 100 years. This compares favourably with traditional methods of repair which are quoted at \$100 - \$150 / m^2 per annum.

Environmental the use of timber reduces extractive industry input by more than 50% and in the end produces a carbon neutral product. That is the amount of carbon dioxide released in the manufacture of the conrete and reinforcement is balanced by the amount stored in the timber. Also these size timber logs are readily available and can be renewed quickly by regrowth forests. Timber girders in sound condition may also be salvaged from reconstructed bridges to be used in the manufacturing.

As the timber is protected from the elements it is anticipated that a life of up to 100 years can be achieved by the modules. A composite timber / concrete has been in service on the Pacific Highway near Kempsey for the past 40 years with no visible cracking in the concrete and no deterioration in the timber girders.

The modules have been implemented at several sites already and indications are that rehabilitations have occurred at costs of half that estimated for traditional timber repairs with on site disruption to traffic reduced from estimated times of six months to actual times of two weeks.

The system lends itself to minimise site work and traffic disruption with much of the existing structure being able to be reused either instantly or in future applications providing a resale value of the existing bridge elements. As the system is modular and demountable future substructure repairs, widenings or relocation is possible.

3. RESEARCH AND DEVELOPMENT PROCEDURES

A research and development project has been initiated to validate the technology the module utilises. This has the objective to develop the concept of the prefabricated timber / concrete composite bridge technology utilising round timbers with a reinforced concrete deck to form individual structural elements. The overall project goal is to provide the Authority with an option for the cost effective rehabilitation and upgrading of the existing timber bridge asset to ensure its ongoing serviceability. The project is relevant to the Corporate Key Result Areas in respect to efficiency, road safety and transport efficiency with implementation to occur as Road Authorities progressively upgrade timber bridges presently not planned for replacement.

A project team has been comprised, a testing specification completed, test modules designed and constructed and a theoretical analysis program tool has been developed. Testing is due to be commenced by May 1995. The testing will be performed at the University of Sydney with two full scale units to both Serviceability and Ultimate Limit States in accordance to the requirements of the 1992 Austroads Bridge Design Code. A loading platform has been devised that replicates the maximum effects of both shear and bending. Fatigue testing will also be performed for 500, 00 cycles as required for roads of Functional Class 1, 2, 3, 6 or 7. Instruments are to be dial gauges positioned so as record measurements of static deflections and longitudinal and vertical slippage between connectors and support material. Test loading to failure will also be attempted up to the safe capacity of the test floor. In addition to the global performance of the system, independent tests of component assemblies will also be performed. These have concentrated on shear plate and bolt connector capacities with shrinkage tests to be performed to gauge the separation of the timber from the concrete and the loosening effect of the shear connectors due to the radial shrinkage of the timber.

As well the project is to load test two inservice existing timber / concrete module decks and based on the success of the initial modules test load smaller sized girder modules and establish a database of applications.

4. EXPECTED OUTCOMES OF THE RESEARCH AND DEVELOPMENT PROJECT

The project being undertaken will validate the structural performance of the timber / concret composite modules with respect to their application in accordance with the 1992 Austroads Bridge Design Code. Thus a cost effective option will be available for the rehabilitation of timber bridges.

Design guidelines and construction specifications will be produced to allow an industry standard engineered solution to be defined for each application.

5. TECHNOLOGY TRANSFER

Integral to the undertaking of the Research and Development project is the transfer of the technology to the industry so that the benefits can be accessed and utilised by all interested parties. It is proposed that nearing the completion of the project, workshops will be conducted to brief prospective designers and builders of the modules as this will permit the rapid adoption of the method as an option for the rehabilitation of the timber bridge asset.

6. ACKNOWLEDGEMENTS

The author would like to acknowledge Don Carter, Manager Bridge Maintenance and Rehabilitation, RTA Technology, Terry Doolan, Bridge Maintenance Manager, RTA North Coast Zone, Grafton for their advice and supply of information and the Technology Strategy Branch, RTA for the opportunity to make this presentation.

Raised Pavement Markers and Adhesives

by

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SUMMARY

Trials have shown that the life of reflective pavement markers is more than doubled by using bituminous adhesive. Bituminous adhesive also provides cushioning effect to the markers due to the vehicle impacts and better preserves reflective lenses of the pavement markers. However, the reflectivity life of the current markers using bituminous adhesive is not commensurate with the life of the adhesive. Better quality markers can take advantage of bituminous adhesive for extended reflectivity life.

1. INTRODUCTION

The Research and Development projects on better marker adhesion (1993/94) and extended reflectivity life (1994/95) have shown:

- Good bituminous adhesives such as Stimsonite result in up to three times increased adhesion life.
- Because bituminous adhesives are soft they cushion the markers and preserve the reflective lenses - acrylic plastic from cracking.
- Reflectivity is therefore also preserved. This can be further enhanced by using tougher markers.

2. ADHESION TRIAL

Trial of a bituminous adhesive supplied by Stimsonite Australia Pty Ltd has proved that this type of adhesive was showing markedly better adhesion properties than the epoxy resin. The trial was carried out on the Pacific, Victoria and Manly roads (asphaltic surface). Standard Stimsonite 88 marker was used for these trials. One marker was adhered by bituminous adhesive at the far end and one marker was adhered by epoxy resin at the near end of the lane line. The results after 21 months of their installation are given below :

Pacific Highway

- Only 10 % were lost using bituminous adhesive. **Fifty per cent** of the remainder were reflecting well. These were mostly on the right hand lane line, so guidance was still good. This length of the Highway (Turramurra to Pymble) gets extremely heavy wear on fairly narrow lanes, due to trucks, especially.
- On epoxy two sets of markers had been lost in 21 months. Reflectivity had gone within 10 months.

Victoria Road

- Only 7 % per cent of the markers using bitumen were lost and the reflectivity of the remaining markers are at a satisfactory level.
- On epoxy, 50 % of the markers were lost and the remainder of the markers are still reflecting well. The lanes here are wider than Pacific Highway and consequently there is less wear and tear.

Manly Road

- Only 5 % of markers were lost using bitumen and 75 % of surviving markers are still reflecting well.
- On epoxy, all markers were lost in about 12 months time.

3. OBSERVATION FROM ADHESION TRIALS

The epoxy resin failures involve fatigue failure of the asphalt surface after about 100,000 vehicle cycles due to its inflexible nature. Bitumen adhesive is more flexible and is able to absorb vehicle impact.

Epoxy resin is relatively harder and therefore the markers showed multiple fractures of their plastic shells. Consequently the reflectivity values of such markers were reduced considerably.

Bituminous adhesive has been successfully used with similar results on sprayed seal on semi-mountainous roads near Canberra. It is believed that the bituminous adhesive will perform well on the open graded AC surface.

For traditional concrete surfaces the bituminous adhesive is not as effective and epoxy resin should still be used.

4. TRIALS ON INCREASED REFLECTIVE LIFE OF MARKERS

Encouraged by the result of longer life, using the bituminous adhesive, improved markers were installed so that they can be compared by the standard markers. Trial was undertaken on the Victoria Road (Gladesville - Glebe Island bridge section) to find the trend in the adhesion life and reflectivity life using the bituminous adhesive and better quality markers.

- Standard Stimsonite 88 markers were placed on epoxy resin at the beginning of lane lines on some sections.
- Stimsonite 88s were placed at the far end of some lane lines, on bitumen.
- A small but tough protected reflector lens Stimsonite 953 was placed on one section, on bitumen (cost $1.60 more).
- Stimsonite 911's were similarly placed on bitumen (cost 60 cents more). These have scratch resistant lenses.
- Catseyes were also placed on bitumen.

The observations in early 1995 showed :

- Epoxy loss rates after 7 months were as high as 30% compared to bituminous loss rate of almost nil.
- The Stimsonite 953 is currently brighter than the Stimsonite 88 and appears to be tougher in strength and reflectivity lens protection. The observations are continuing and laboratory checks will be conducted.
- The Stimsonite 911 is also brighter than the Stimsonite 88.

The trials are under observation.

5. CONCLUSIONS

- Use of less toxic materials (bitumen) has improved some aspects of occupational health and safety issues. Also because of much longer life of markers, the frequency of marker replacement has been reduced and consequently the gang exposure to traffic has also reduced.
- Longer life of markers may result in saving up to $1 million per year. The saving may be used to extend the network coverage.

- The improved level of reflectivity has improved the highway delineation and the highway safety.

6. FUTURE DIRECTIONS

- Assess a future all Australian marker made from recycled PET plastic, but of excellent appearance and quality, and very high reflectivity. Performance on four adhesives shall be assessed, as well as its effect on the performance of markers reflectivity.

- Check two other brands of bituminous adhesive currently in use (Victoria and New Zealand).

- New Ciba-Geiggy flexible epoxy shall be assessed. The Company is eager to regain lost ground in the market.

- Feasibility study shall be undertaken to ascertain the possibility of improving the method of marker placement and development of objective method to monitor the condition of the markers.

Flyash Pavement Field Trials

by

David Dash
RTA Pavements

1 INTRODUCTION

Historically, the Romans used volcanic ash from Pozzuoli, with lime, as a cement. The similarity of volcanic ash and flyash, first appearing in the 1920s from furnaces burning pulverised coal, resulted in the use of flyash with portland cement in concrete. The similar behaviour and usefulness of these ash materials also led to the term "pozzolan" being coined generally for reactive ashes.

Flyash has been used in Australian road construction for many years, but in relatively low volume applications. These applications include blending with portland cement; lime-flyash as a stabilisation agent; and flyash filler in asphaltic concrete.

Offshore, flyash has also been used over the years, or trialled, in high volume applications in roads, namely:

- flyash as an embankment or fill material;
- flyash as a pavement material in its own right, with added lime or cement.

The flyash pavement application is currently undergoing local field trials, associated with the Eraring Power Station on Lake Macquarie near Newcastle, NSW. These field trials, already very promising in terms of pavement performance, are the subject of this paper. They are being sponsored by:

- Pacific Power, NSW
- Roads and Traffic Authority of NSW
- Lake Macquarie City Council.

Additionally, the Ash Development Association of Australia will be involved in the publication of performance and design data.

2 LITERATURE REVIEW

Before the current program of field trials was initiated, the literature on flyash in roads was reviewed[i]. Since the early 1950s, much literature has been written on lime-flyash as a cement for road stabilisation, all of it being quite positive. Regarding high volume flyash applications, some examples of impressive performance of road embankments or fills were reported in the UK[ii]:

- In 1952, pond ash (a mixture of flyash and bottom ash) was used to fill a disused railway cutting 6m deep, by end tipping. The ash was very wet (55% moisture content) and compaction was not attempted. After two months of trafficking on a temporary road on this fill, a settlement of 40mm had occurred. The permanent road was then built and, remarkably, no further settlement occurred.
- In 1960, a road was built over a marsh by removing 2m of unsuitable material and end filling with pond ash into 1.5m of water. After standing for one day, the embankment was compacted by rolling. The ash was also assessed here to be an excellent pavement subbase material. On other sites, pond ash or flyash performed extremely well in fills behind bridge abutments, in embankment 9m high, and as lightweight fill over flood archways.

Later, in the USA, flyash embankment heights up to 23m were reported, in some cases over soft, compressible ground[iii]. Also, several successfull US field trials of stabilised flyash road pavement were reported[iv,v,vi,vii]. The largest and most recent of these trials comprised 37,000 m^2 of lime stabilised flyash pavement. Comprehensive guidelines were published in 1986 for the use of flyash as a road construction material[viii].

In Australia, a field trial of stabilised ash road pavement, containing more than 30% flyash, was established in South Australia in 1992[ix]. This project led to the current field trials at Eraring in NSW, using straight flyash stabilised with cement as the pavement base material.

3 FIELD TRIAL OBJECTIVES

As the feasibility of stabilised flyash pavements had been verified offshore, and because of the potential benefits involved, a series of local field trials was planned with the following objectives:

- Develop local expertise in the handling of stabilised flyash pavement material, which is most unusual for a road base being extremely fine grained and also lightweight.
- Provide a local demonstration of the performance of a flyash pavement under heavy traffic loading.
- Determine the service life and failure mode of flyash pavement using the Austroads' Accelerated Loading Facility (ALF).

The stabilised flyash material has the appearance of fine grained cement mortar. An obvious distinguishing feature when handled is its very light weight, which is consistent with low stiffness (or modulus) relative to strength. This property of low stiffness combined with high strength is expected to provide benefits in pavement performance. The material's propensity for cracking should be less than for conventional materials of similar strength.

This benefit may be offset to some degree by the fine grained nature of the material, which could be expected to lower resistance to abrasion and erosion. Repetitive movement at cracks might have a more significant degrading effect than for conventional materials. On the other hand, the pozzolanic nature of the material will provide a degree of self (autogenous) healing of cracks.

The relative importance of these interacting properties can only be determined by pavement performance studies. Short term performance is to be studied using accelerated loading on thin pavement sections on the Eraring Power Station site. Long term performance, which ultimately is the best indicator, could be studied effectively on the coal haul road to the power station, where the traffic loading is heavy and accurately measured.

4 ALF TEST SITE

A site was selected within the power station area, on which an ALF test could be conducted. The site was on an existing road, but traffic could be diverted around the test pavements for the duration of the project. Because of the favorable situation for construction, the ALF test pavements were constructed first, to provide the necessary "learning curve" experience.

The four test pavements involved were 300 mm thick, laid out as shown in Figure 1, and comprising:

- flyash with 8% cement;
- flyash with 4% cement;
- lightly bound fine crushed rock (FCR) control section;
- 4% cement stabilised flyash subbase with lightly bound FCR base.

These pavements were constructed in May 1994, and will have been curing for one year when the ALF testing commences commences in May 1995. The ALF test will be conducted by the Australian Road Research Board, over a period of about four months. All sections were surfaced with a sprayed seal, and before the ALF testing, 25 mm of asphalt will be laid. A 50 mm layer of bottom ash, which is very permeable, was placed between the subgrade and pavement to facilitate wetting of the subgrade, if necessary during the ALF test.

In ten months of curing so far, the flyash pavements have not developed any shrinkage cracks, which is a pleasing and surprising result. The optimum moisture contents were about 30% and 20% in laboratory and field respectively. The unconfined compressive strength results were about:

3.5 MPa at 28 and 90 days for 4% cement stabilised flyash;

13 and 15 MPa at 28 and 90 days for 8% cement stabilised flyash.

Compaction of the stabilised flyash was found to be very easy, using two passes of a padfoot roller and four passes of a pneumatic-tyred roller. Finishing of the surface presented some difficulties, with the outcome being an acceptance of minor surface blemishes as characteristic of the material. An appropriate surface treatment with shape correction properties, such as asphalt or microsurfacing (slurry), would therefore be required in normal practice.

The stabilised flyash material was supplied by Flyash Australia Pty Ltd from its Vales Point plant, at a moisture content of about 20%. Construction was carried out by Lake Macquarie Council[x], and testing by the Roads and Traffic Authority[xi,xii]. Further testing for material characteristation is part of a PhD research project by the University of Technology, Sydney, involving repeat-load triaxial and indirect tensile testing.

4 COAL HAUL ROAD, ERARING

After gaining some experience with stabilised flyash pavements, the second field trial was established on a heavily trafficked private road; the Coal Haul Road approaching Eraring Power Station. The following two flyash pavement sections, laid out as shown in Figure 2, were designed for a forty year life:

- 450 mm of flyash stabilised with 8% cement;
- 300 mm subbase of 8% cement stabilised flyash with 150 mm base of lightly bound crushed rock.

These pavements were surfaced with 50 mm of asphalt to resist braking forces from the coal trucks approaching the power station gate and weighbridge. The weighbridge records will provide an accurate axle loading history for the trial.

The full depth flyash section has been located near the gate where the traffic loading will be more severe, with the occurrence of slower vehicle speeds and stopping. Also, the high braking stresses on the pavement surfacing will provide a severe test for the interface between the asphalt and stabilised flyash. Attention was given to providing an effective interface, by ensuring some penetration of the bitumen prime into the stabilised flyash surface[11].

So far, after six months of coal truck traffic, no cracking or other distress is evident in these trial pavements.

5 PAVER TRIALS

The stabilised flyash in the above field trials was placed with conventional plant (loader and grader), but the possibility of using a paver has been investigated. Initially, a trial paving exercise was carried out using a paving machine with a floating screed, as used for roadbase material. The flyash material passed through the paver without sticking, but layer thickness could not be controlled as the floating screed was too heavy to "float" on this lightweight material.

A second paving trial was undertaken using a concrete slipform paver, which is designed for flowable material. In this case, the control of layer thickness was not a problem. However, the moisture content of the material (at 20%) was not optimal for compaction with the internal vibrators on the paver. A further trial is proposed with a moisture content of about 30%, the laboratory optimum at which slight slumping of the material was observed. At this higher moisture content, the material tends to be difficult to tip and the use of conventional tipping trucks for transport may not be appropriate.

If full compaction of the stabilised flyash can be achieved with the slipform paver, this method of placing flyash pavement will overcome the surface finishing problems experienced to date.

6 PROPOSED FIELD TRIALS

Three further field trials are currently proposed:

- **Eraring main road interchange** - a stabilised flyash overlay proposed to the northbound on-ramp of the interchange, which is 900 metres long. The flyash overlay would be 300 mm thick, to be placed on the existing chip seal. This would be an excellent opportunity for a rigorous trial of the slipform paver.

  At the same time, for the southbound on-ramp a demonstration project is proposed of deep-lift stabilisation using flyash-based "cement", which would be a blend of 65% flyash with 25% lime and 10% cement. This Triblend has been used for some time by Wyong Council for treating roadbase material. Part of this southbound ramp will have a full depth flyash pavement, stabilised with 8% cement.

- **New mine access road** - a cement stabilised flyash base, with a lime stabilised bottom ash subbase, is under consideration for a proposed mine access road about one kilometre in length. A flyash pavement specification has been prepared for this project, with the optional use of a concrete slipform paver for construction.

- **Existing unbound pavement** - the performance of a plain flyash subbase, with a gravel base and chip seal, will be monitored. So far, this road has been performing well under construction traffic for a new ash dam embankment, also consisting of unbound flyash (which is practically impermeable).

7 BENEFITS OF FLYASH PAVEMENTS

The potential benefits of flyash pavements relate to the environment and economies in construction. The existing market demand for flyash is much smaller than the supply, and large quantities of flyash are being stored at power stations. Clearly, there are environmental benefits in using these stockpiled materials on two counts:

- improved land use around power stations;
- reduced demand for quarry products, and consequently, reduced environmental impact from quarries.

The flyash stockpile quantities are relatively small in comparison to the usage of road pavement materials, suggesting that all of the flyash available could be used in road pavements. There is also potential for the use of flyash in road embankments, especially over soft ground. However, the cost of transport must be considered.

For road construction in areas close to power stations, the use of flyash fills and pavements could be very cost effective.

9 CONCLUSION

The local field trials of stabilised flyash road pavements are encouraging for the development of this new application for flyash. A heavy duty pavement is performing well under coal truck traffic, and a suite of test pavements is ready for accelerated loading.

Laboratory testing of the stabilised flyash material supports its use in road pavements, as being appropriate. Further material characterisation is being undertaken as a University postgraduate project.

Future field trials are planned to develop slipform paving as a construction technique, and to provide additional performance data. As well as stabilised flyash pavements, the performance of plain flyash as a subbase layer will be assessed.

The benefits of flyash pavements are related to both the environment and economies in construction. These benefits will be quantified as the short and long term performance of the flyash pavements emerges.

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Concrete Paving Technology

by

Geoff Ayton
RTA Technology

Concrete paving technology

Technology Transfer Workshop

Wollongong

3 May 95

Geoff Ayton
Pavements Branch
GA:T:TT5-95

Concrete pavement technology

- Concrete pavements overview
- Recent challenges (problems)
- Current R&D focus

✈ Pavement outputs

Pavements ⇨ 40% of RTA annual budget

✈ *Concrete pavements*

100 lane-km p.a. @ 5m wide

Construction expenditure ~$30M p.a.

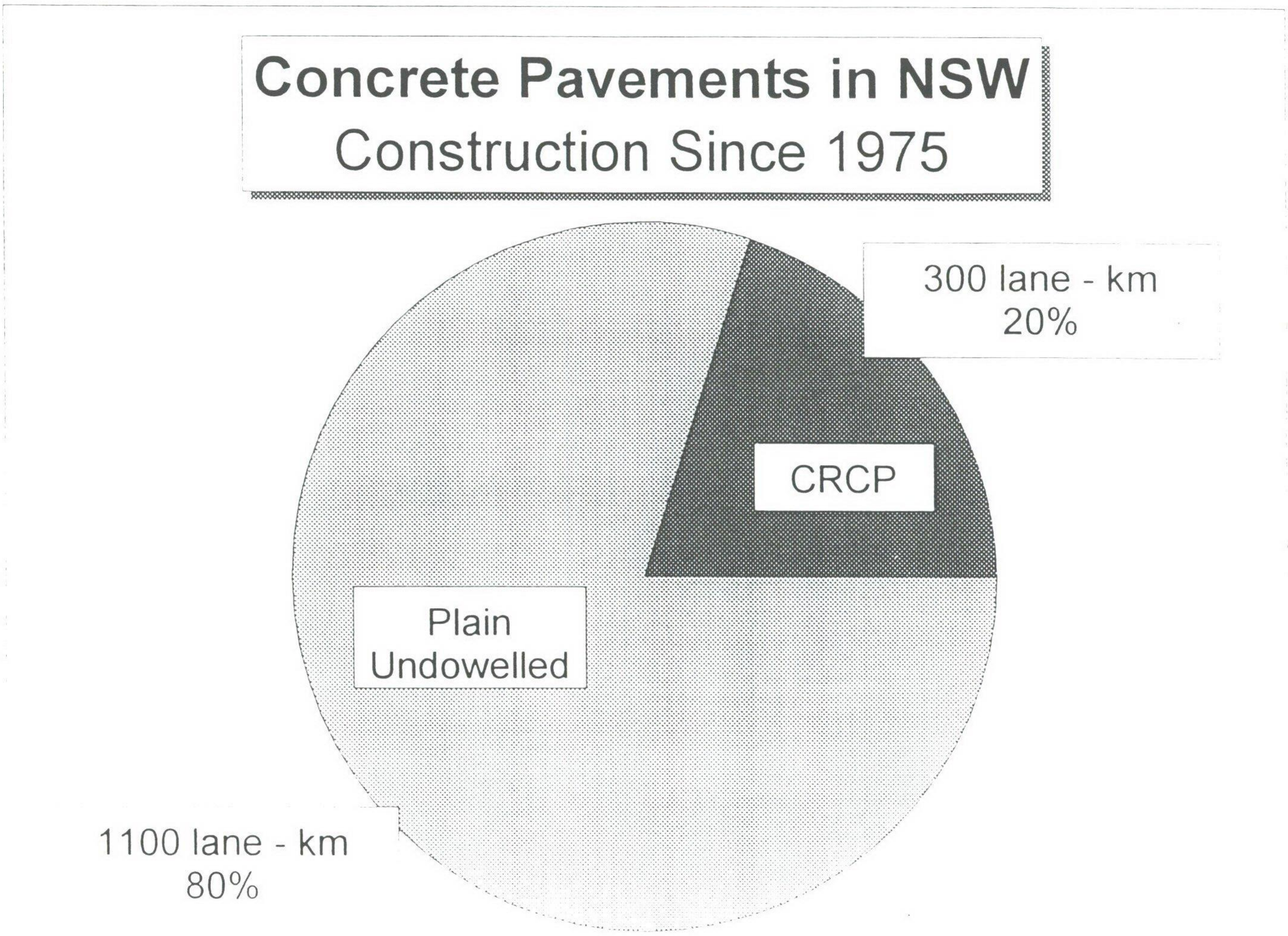
115,000 m^3 p.a. (base only)

~ 300,000 tonnes p.a. (base only)

cf Asphalt ⇨ 1 M (+) tonnes p.a., all uses

Worldwide: on the basis of current annual output:

① USA ② Germany ③ Austria ④ **Australia** (NSW)


Concrete Pavements in NSW
Construction Since 1975
300 lane - km
20%
CRCP
Plain
Undowelled
1100 lane - km
80%

☑ Concrete: Why only NSW?

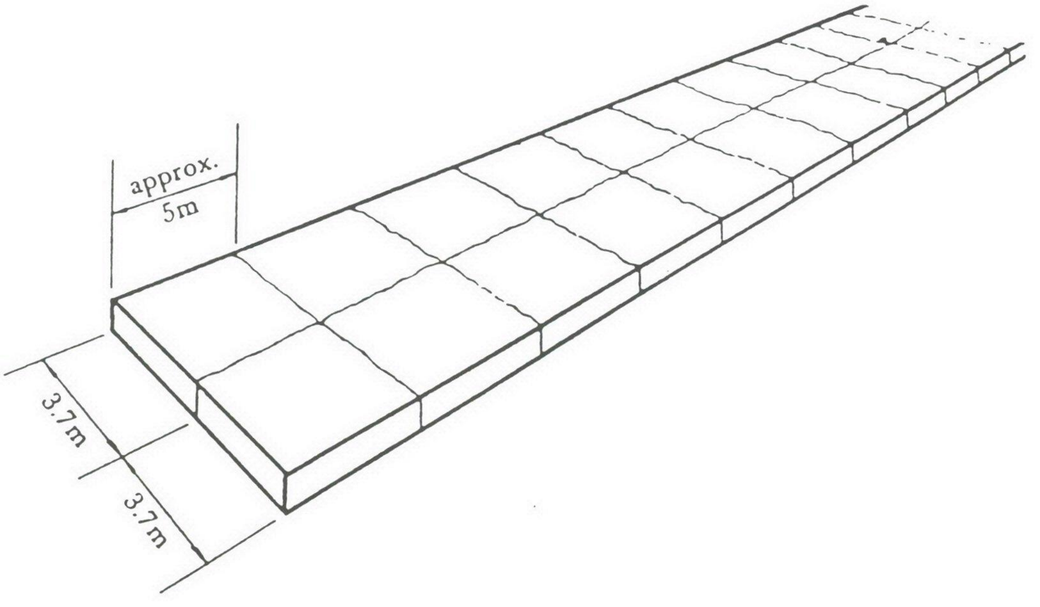
- ❒ CV volumes
- ❒ Subgrades
- ❒ Gravel availability
- ❒ *Existing* vs *New* technology

☞ **Federal DOT ⇨ ALF trial**

☞ **Isolation in technology development**

☒ Recent *challenges !*

1. F3; CRCP/subbase ~~de~~ bonding
2. Cullarin-Yass "V-cracking"
3. Wilton Bypass; shoulder jointing
4. Cumberland Hwy; subgrade
5. F3; Mt Colah mixing
6. Compaction

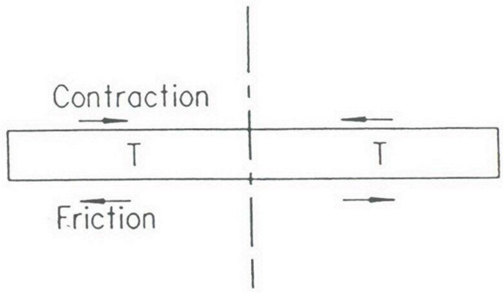


Typical cracking pattern in unreinforced pavement constructed without control joints.

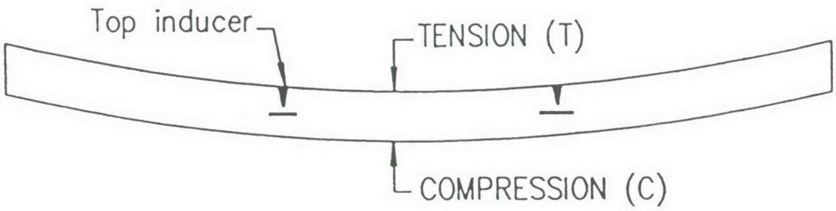
3.

1. FALLING TEMPERATURE

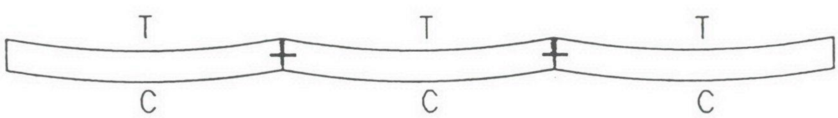
(i) Contraction



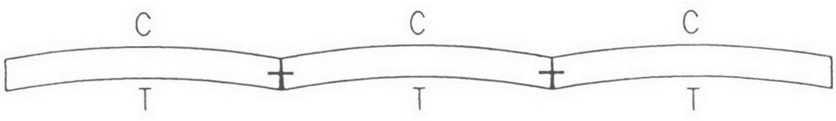
(ii) Curling



but following crack induction.........



2. RISING TEMPERATURE

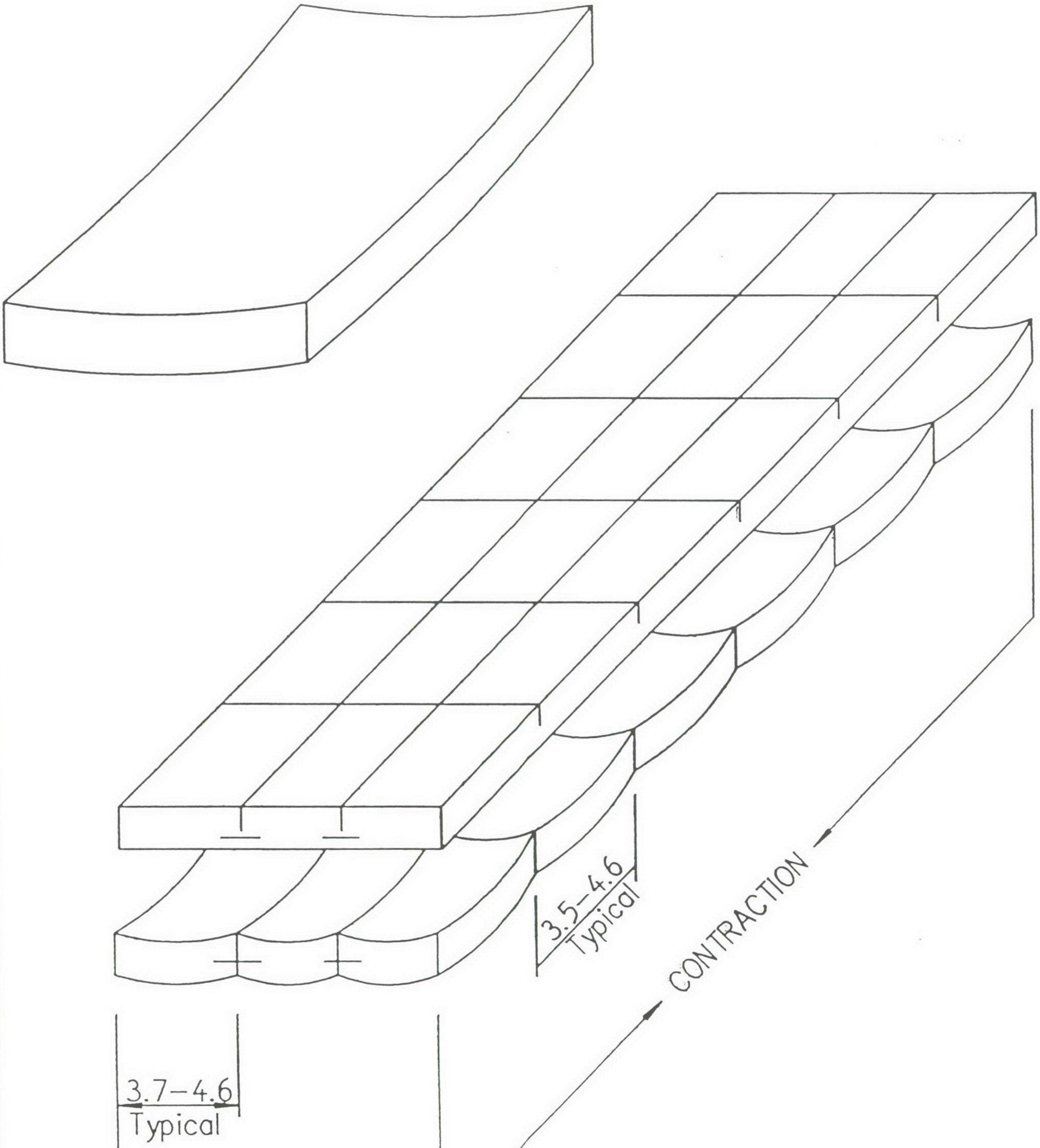


3. MOISTURE

WARPING

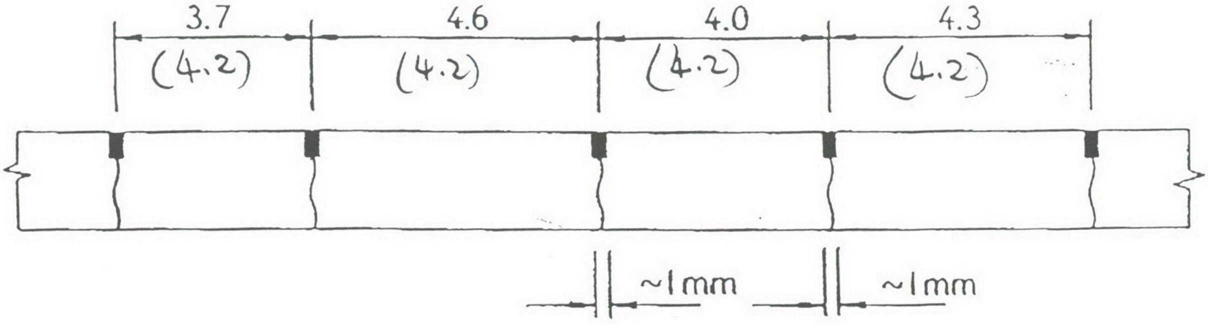
TEMPERATURE AND MOISTURE EFFECTS ON CONCRETE SLABS

+ .

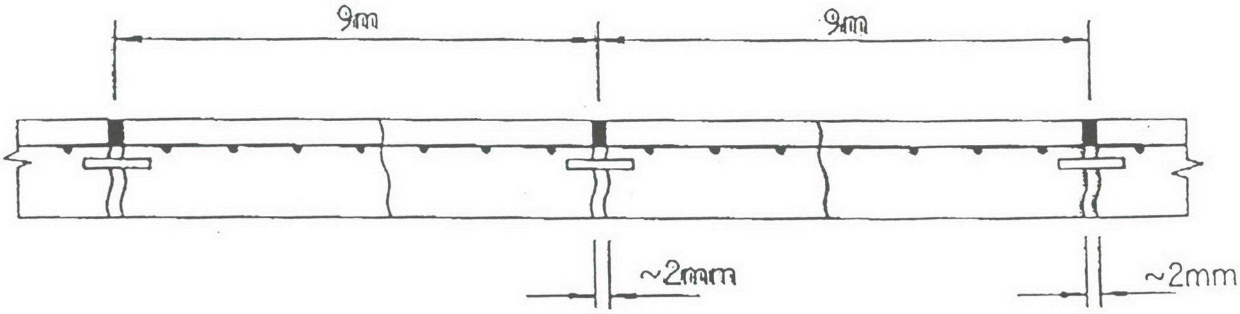


CURLING & CONTRACTION

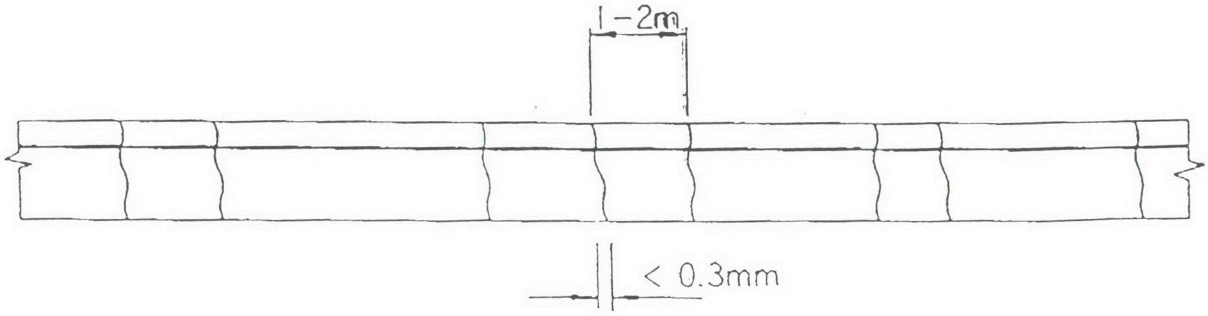
PLAIN CONCRETE PAVEMENT (PCP)



JOINTED REINFORCED (& DOWELLED) (JRCP)



CONTINUOUSLY REINFORCED (CRCP)



LONGITUDINAL SECTIONS

R T A

CRCP "*designer*" cracking

- Design balance : steel/concrete)
  plus) ⇨ crack spacing & width
  thermal shock)
  plus)
  Subbase friction ⇨)

⇩

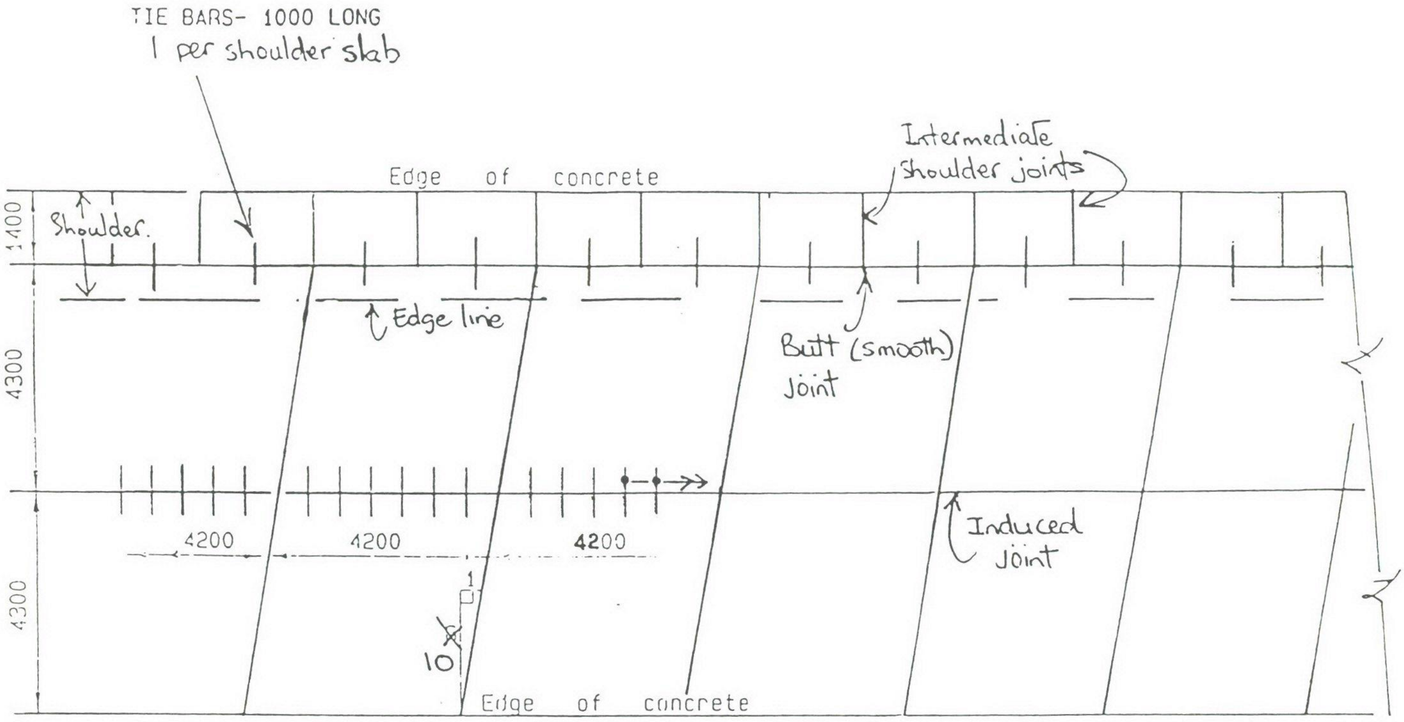
⇩

- Subbase texture ⇦
  and
  subbase curing; wax *vs* chlor. rubber *vs* hydrocarbon

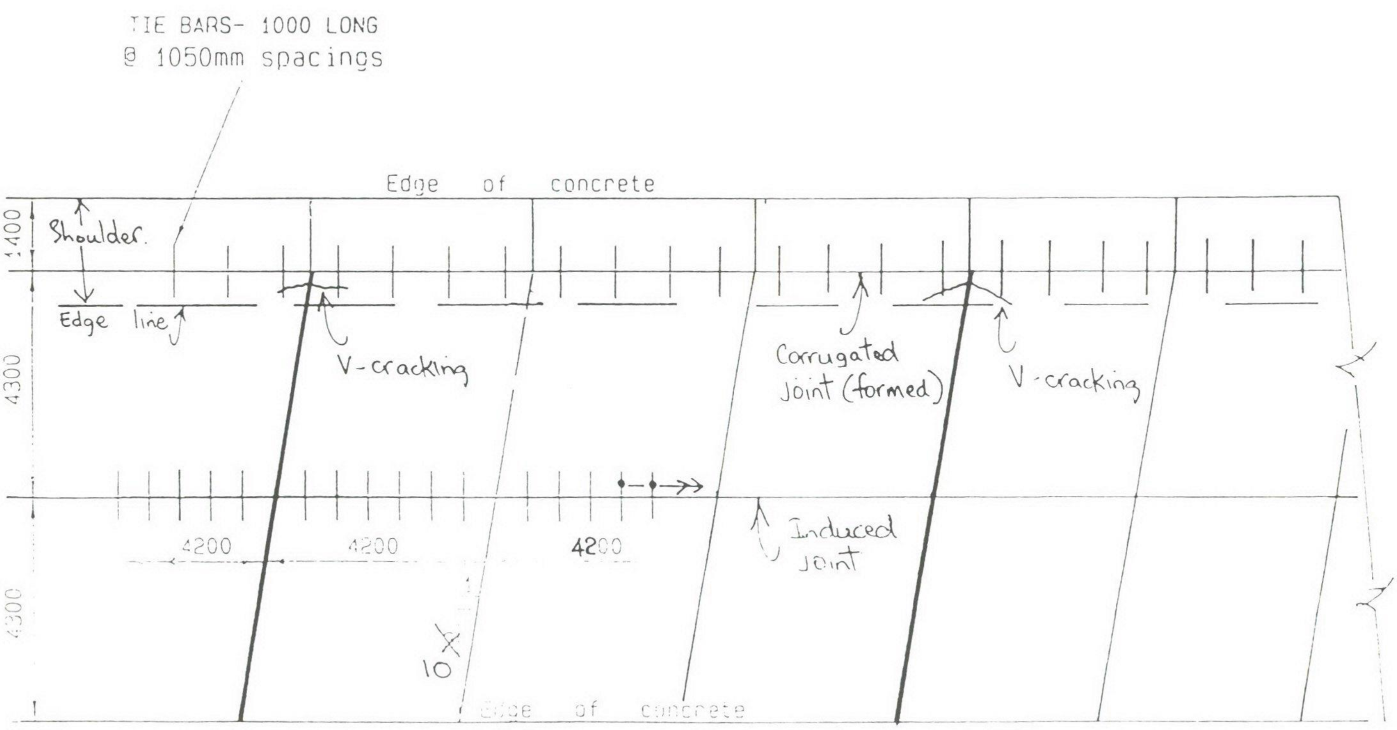
PCP "*designer*" cracking

- ▲ **strength gain (tensile & flexural)**
  plus
  ▲ thermal shock
  plus
  Subbase friction ⇨
  ⇩
  ⇩
- **Subbase texture** ⇦

  subbase interlayer; (wax **x** 2) cf (wax + seal)

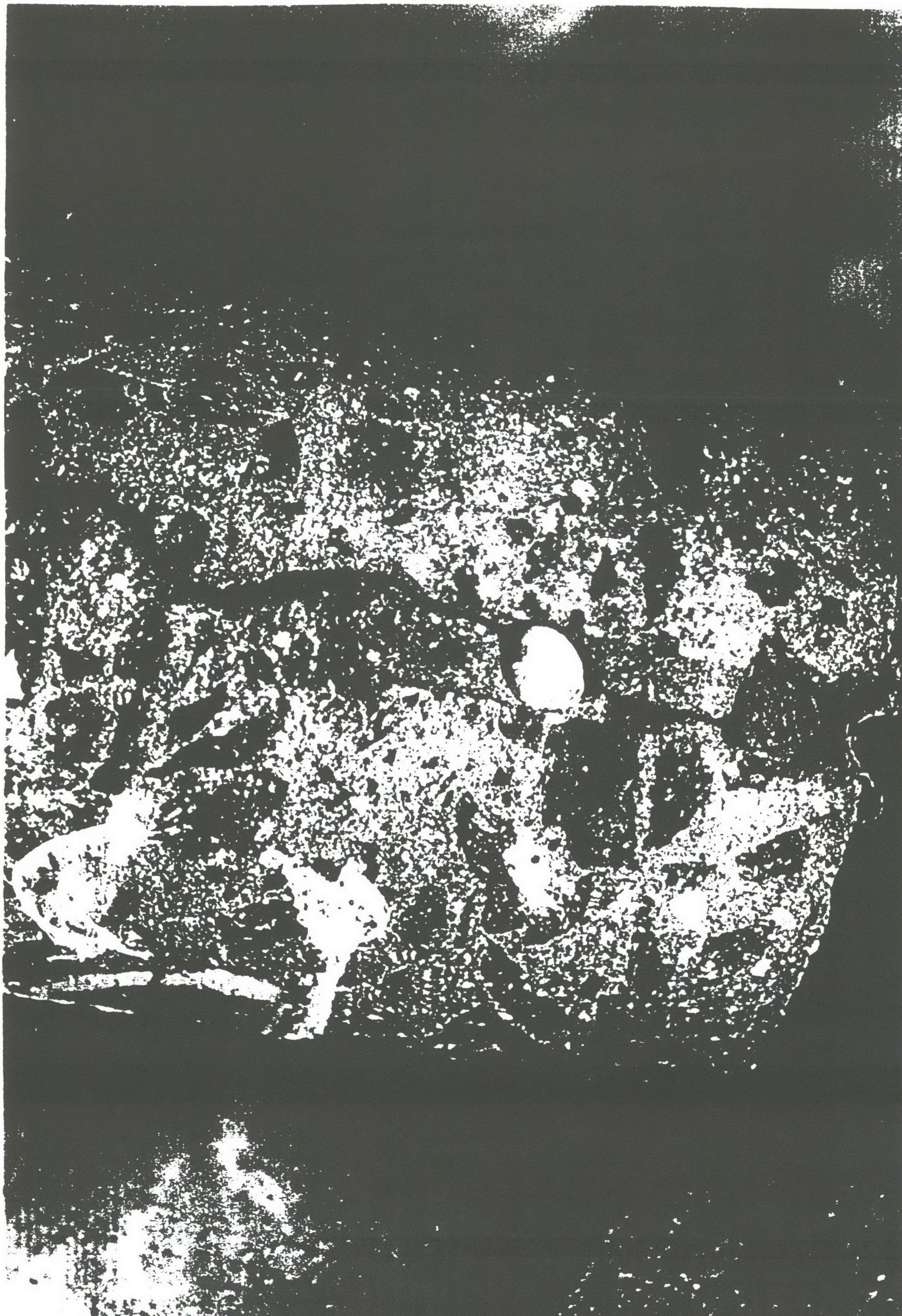


Superseded plan layout
(pre-1993 approx)



Revised plan layout
(post-1993 approx)

Typical short "arrow" cracking.



"V"-cracking in PCP

Appears to have resulted from the combined effects of:

- ❒ uneven joint opening
- ❒ summer c'way then winter shldrs
- ❒ single sawcutting (D/4 x 7 mm)
- ❒ no sealant in vertical joint face
- ❒ Flyash ⇨ ⇨ enhanced workability

leading to:

- ❒ mortar ingress into transverse joints

and subsequent compression stress

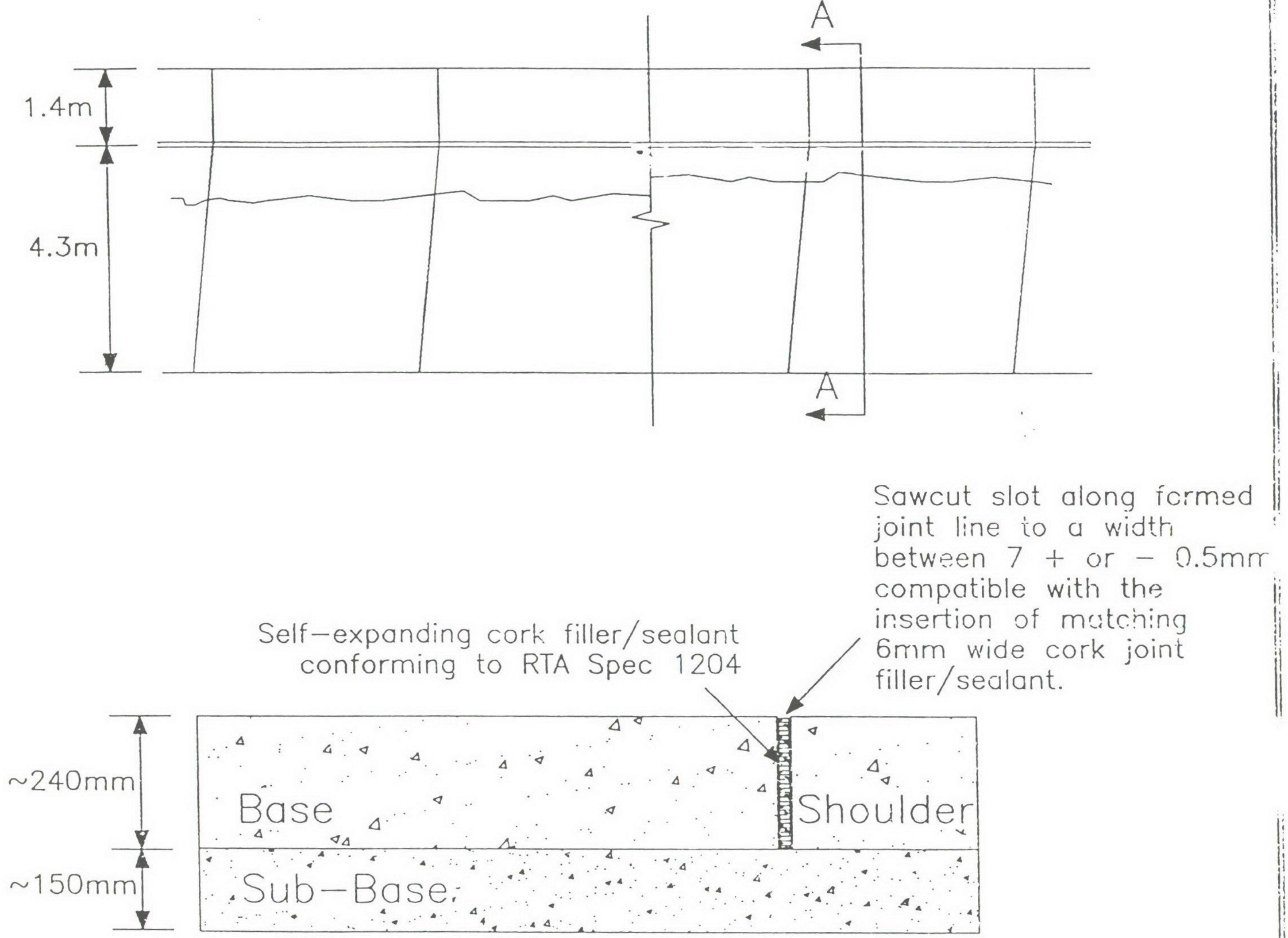
Wilton Bypass

- ⇨ **Fully bonded shoulder joint**
- ⇨ **Base/subbase bonding**

Doubts remain as to:

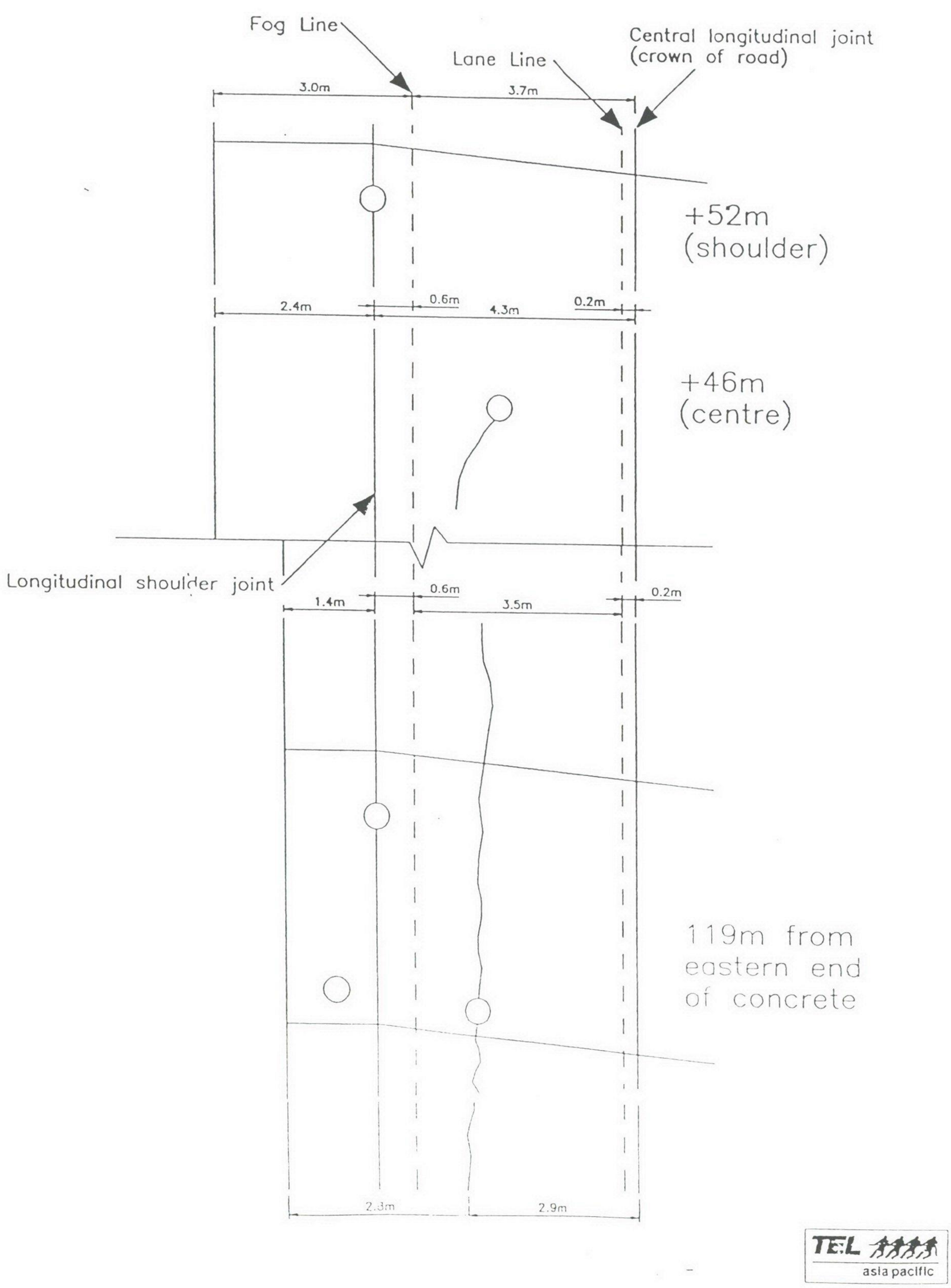
- ❒ **Reasons for atypical shoulder bond**
  (environmental stresses should have induced cracking in the immature shoulder concrete at the joint within days of placement)
- ❒ **Contribution of tiebars to bonding**
  (international literature strongly indicates that reinforcement rarely prevents cracking in pavement slabs; JRCP-D behaviour is an example)
- ❒ **Reasons for atypical interlayer bond**
  (a treatment of wax + seal typically provides such good separation that uneven opening of transverse contraction joints commonly occurs)

Figure 2 – Wilton Bypass
Concrete Pavement Remedial Work



Section A–A

Figure 1 – Core Locations Wilton Bypass



Rigid pavements

Current RTA research

Geoff Ayton
Pavements Branch
RTA Technology

GA:T:R&D-VIC1

Rigid Pavements

- Austroads Thickness Design
- Pavement modelling
- ~~ Surface characteristics
- Model specifications;
  - Construction: review
  - Maintenance: compilation
- Manuals:
  - Design & construction: review
  - Maintenance: review

Cumberland Highway

Failure mechanisms:

- ⇨ Base; substantial cracking
- ⇨ Subbase fracture
- ⇨ Subgrade pumping

Contributing factors appear to have been:

- ❐ **Inadequate pavement thickness**
  (Under now-superseded design methods)

- ❐ **CVAG's; volume & growth**
  (both appear to have been under-estimated.)

  Note that the ESA growth rate may be very different to the CVAG growth rate; see RTAT Directions Circular 95/3)

- ❐ **Poor subgrade**
  (Improvement of subgrade would now be warranted; see RTAT Directions Circular 95/4. Further development work is required, and additional guidelines will be provided in the Austroads Design Guide.)

Austroads thickness design

& RTA Form 76

- **AASHTO comparison**
- **LSF** (PCA) **cf Reliability** (AASHTO)
- **Minimum subgrade conditions**
- **Case studies ⇨ Clybucca CRCP**
  ⇨ Tumblong PCP
- **Revised guidelines for LSF & GF**

Case study 1: SH2 Tumblong

- Opened 1983
- Pavement design: PCP 200 ± 20 (on LCS 100)
- Actual: 185-195
- Construction quality: very good

Case study 1: SH2 Tumblong

AASHTO analysis using
actual thickness of 190 mm

AASHTO Reliability	Design Life (ESA's)	
60	2.4 E 7	
75	1.8 E 7	
85	1.4 E 7	cf Traffic to date
95	9.3 E 6 ⇖	1.1 E 7

Case study 1: SH2 Tumblong

40 year design
Design traffic; 1×10^8 CVAG (7×10^7 ESA)

AASHTO Reliability	PCA LSF	Thickness
60	1.1	230
75		240
85	1.2	250
95	1.3	270

Case study 2: SH10 Clybucca

- Opened 1976
- Design: CRCP 230 (23 MPa min, 28 MPa actual)
  on LCS 130 (without shoulder)
- Actual thickness: 230-245 mm
- Construction quality: very good

Case study 2 SH10 Clybucca

40 year design
Design traffic; 8×10^6 ESA

AASHTO Reliability	PCA LSF	Thickness
60	-	220
75	1.0	230
85	1.1	240
95	1.2	260
98	1.3	270

Case study 2: SH10 Clybucca

AASHTO analysis using actual thickness 230 mm

AASHTO Reliability	Design Life (ESA's)
75	1.6 E 7
85	1.2 E 7
95	8.3 E 6

cf Traffic to 1995

⇦ 5.5 E 6

Case study 2 SH10 Clybucca

40 year design (by PCA)
Design traffic; 8×10^6 ESA (cf 1995 re-estimate 1.6×10^7)

PCA LSF	Thickness	
	without shoulder	*with shoulder*
1.1	240	210
1.2	260	220
1.3	270	230

Pavement modelling

Strand6 finite element package

- Joint design
- Slab geometry
- Shoulder design
- Subbase & subgrade
- Thermal gradients, curling

performance

monitoring (ALF ?)

Concrete technology

- Accelerated acceptance testing
- Characteristics of field concrete
- Non-destructive test methods

- Materials recycling
- Industry training

Load safety factor & Reliability

	PCA Load Safety Factor		
AASHTO Reliability	60%	85%	95%
Undowelled jointed	1.1	1.2	1.3
Continuously reinforced and dowelled jointed	1.0	1.1	1.2

Accelerated acceptance testing

- AS 1012 Part 19
- 28 days ⇨ ⇨ ⇨ 27 hours
- Switzerland & Georgia (USA)
- Glebe Island Bridge project
- Future paving trial

Laboratory versus field concrete

- Lab: constant & controlled
- Field: variable temperature & moisture

- Strength / load capacity / trafficking
- Field maturity (summer & winter)
- To core, or not to core ?

☺ Non-destructive test methods

- Ultrasonic pulse
  - insitu strength
  - cylinder density
- Nuclear density

for both field and laboratory

Austroads Revised Pavement Overlay Design Procedures

by

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Largely Abstracted from the ARRB 17th Conference Paper, "The Development of the Australian Mechanistic Approach to Overlay Design", D.W. Potter et al (1994b)

1. Introduction

In 1987 a mechanistic procedure for the design of new flexible pavements was adopted in Australia for use nationally, following the publication by NAASRA of "Pavement Design – A Guide to the Structural Design of Road Pavements" (NAASRA 1987). The procedure was unaltered in the subsequent update released by AUSTROADS in 1992 (AUSTROADS 1992).

With the widespread use of this method, it became apparent that there was a need to establish overlay design procedures consistent with the procedures for design of new pavements.

In 1989, a national working group was formed to overview a research project required to develop these new approaches to overlay design. The project was undertaken by the Australian Road Research Board for AUSTROADS, the national association of Australian state road authorities. The objective of the project was to develop procedures which enable pavement life and strengthening requirements to be estimated from knowledge of layer thicknesses, material types and surface deflections measured by the range of deflection testing devices currently used in Australia.

Design procedures for overlays on both flexible and rigid pavements have now been released in interim form (AUSTROADS 1994). These procedures cover the design of flexible overlays (granular, asphalt or mixed material) or concrete overlays on existing flexible pavements, and the design of asphalt or concrete overlays on existing rigid pavements. The following sections provide a brief overview of the procedures for each of these design situations but, for a more complete coverage, the reader is referred to AUSTROADS (1994).

2. Flexible Overlays On Existing Flexible Pavements

Two design procedures for flexible overlays on flexible pavements are included in AUSTROADS (1994). First, a fully mechanistic overlay design procedure has been developed based on back-calculation of layer moduli for the existing pavement from either Falling Weight Deflectometer (FWD) or Benkelman Beam (BB) deflections, using the computer program EFROMD2 (Vuong 1991). Although this procedure is the preferred procedure for overlay design, it is time consuming and requires engineering judgement to select appropriate seed values for the layer moduli and to accept back-calculated layer moduli. Hence, it was perceived that there was an additional need to develop a simpler method of overlay design based on mechanistic design principles. This paper outlines both the General Mechanistic Procedure (GMP) and the AUSTROADS Simplified Mechanistic Overlay (ASMOL) procedure developed from the GMP. More detailed information is provided in Jameson and Potter (1993) and Potter et al. (1994a)

3. General Mechanistic Procedure

Principles of the Procedure

For the design of new flexible pavements, the mechanistic procedure can be summarised in the following two relationships:

Response Model

Layer Thicknesses + Material Properties + Load => Pavement Response

Performance Model

Material Properties + Pavement Response => Pavement Performance

To adapt it for overlay design, a third relationship (termed an Inverse Response Model) is needed to allow the properties of the materials in the existing pavement to be estimated from the measured surface deflections. We then have:

For existing pavement:

Inverse Response Model

Layer Thicknesses	+	Load	+	Pavement Response	=>	Material Properties

For proposed upgrade:

Response Model

Layer Thicknesses (inc.overlay)	+	Material Properties (inc.overlay)	+	Load	=>	Pavement Response

Performance Model

Material Properties (inc.overlay)	+	Pavement Response	=>	Pavement Performance

Hence, a mechanistic procedure for the design of overlays is, in principle, identical to the mechanistic procedure for the design of new pavements except that there is an initial phase in which an inverse response model is used to determine the properties of the materials in the existing pavement from the measured response of that pavement to a known load. In practice, the measured response is the deflection of the pavement surface (as recorded by a BB, FWD, etc.). Details of the load which produces the surface deflection (BB Truck or FWD, etc.) form part of the input to the inverse response model.

For the design of NEW flexible pavements, the AUSTROADS Guide uses the computer program CIRCLY (Wardle 1977) as the response model, with relevant responses being the horizontal tensile strains developed at the bottom of bound (asphalt or cemented) layers and the vertical compressive strain developed at the top of the sub-grade. These aspects have been carried forward unchanged to the overlay design procedure. However, if there are bound (asphalt or cemented) materials in the existing pavement, judgement is needed in determining the relevant critical strains for the overlaid pavement, and their locations.

The performance models (fatigue of asphalt and cemented materials and permanent deformation of the sub-grade) used in the design of new pavements have been carried forward for use in the overlay design procedure.

The Inverse Response Model recommended is EFROMD2 (Elastic properties FROM Deflections) developed by the Australian Road Research Board (Vuong 1991). It is a PC-based program which uses CIRCLY in an iterative manner to determine the elastic properties of the pavement and sub-grade materials which give the best fit between measured and estimated deflections. Response models other than EFROMD2 may be used, provided they have the appropriate modelling capabilities.

For deflections measured with the BB, it is important to take cognisance of the fact that during the course of a test, in addition to the beam tip, the reference beam (via its supports) also experiences deflection movements. Hence the measured deflections differ from the actual deflections experienced by the pavement. EFROMD2 takes this into account by converting the estimated deflections to deflections which would be measured by the Benkelman Beam, before making the comparison with the deflections which were measured.

As with the response model CIRCLY, EFROMD2 is capable of modelling pavement layer interfaces as having either no slippage between adjacent layers or no friction between adjacent layers. The former condition (no slippage) is usually adopted.

4. Specifics Of The Procedure

A flow-chart of the procedure is presented in Fig. 1. The steps in the procedure are conveniently grouped as follows:

(a) Determine those properties of the existing pavement needed for the Inverse Response Model (EFROMD2), together with measured deflections, and determine the Young's Moduli (E-values) of the existing pavement and sub-grade layers under the measurement conditions (magnitude and speed of deflection load, asphalt temperature).

(b) Select an overlay configuration and assign values to the elastic properties of the materials in the overlay configuration.

(c) Revise the moduli of existing asphalt and granular and sub-grade materials (determined in (a) above) to account for differences between the measurement conditions and the operating conditions after overlay (speed and magnitude of loading, pavement configuration, temperature of asphalt).

(d) Input the properties of the overlaid pavement (existing pavement plus overlay) into CIRCLY, together with the appropriate loading and determine the values of relevant critical strains.

(e) Using the appropriate performance relationships, determine, for each distress mode, the allowable number of repetitions of the applied load.

(f) Determine, from design traffic information, the design number of repetitions of the applied load for each distress mode.

(g) Check that, for each distress mode, allowable repetitions exceed design repetitions.

(h) If the selected overlay configuration is unacceptable (design repetitions exceed allowable repetitions for any distress mode) repeat the process starting at step (b).

5. The Austroads Simplified Mechanistic Overlay (Asmol) Procedure

The ASMOL procedure is a simplified version of the GMP in that the roles played by the Inverse Response Model and the Response Model in the GMP (both of which are computer software packages) are performed in ASMOL by simple algebraic equations. Hence, in principle, the design can be undertaken on the back of an envelope – albeit preferably A4 size. The major task in producing ASMOL was the development of the relevant equations to encompass the broad range of pavement types and conditions and temperatures present in the field. These equations were developed by regression analysis of data generated from CIRCLY analyses of appropriate pavement configurations.

Use of ASMOL Procedure

A flow-chart of the Procedure is provided in Fig. 2. The following sections describe the steps involved in the procedure.

Establish pavement configuration and measure deflections

The information needed for the existing pavement, together with relevant sources, are obtained from a table (Table 10.3.3.2) in the Interim Release of the overlay revision (AUSTROADS, 1994). Another table (Table 10.3.3.3) indicates generic pavement configurations, together with valid ranges of layer thicknesses, from which the designer selects that configuration corresponding to the existing pavement (Existing Pavement Type).

To select the Existing Pavement Type, the designer needs to specify how many pavement materials there are, what materials constitute each layer, whether the asphalt surface layer (if present) is cracked or sound, whether cemented layers (if present) are cracked or sound, and whether the thicknesses of existing pavement layers are within the specified ranges.

For each Existing Pavement Type, the procedure refers to a table to identify those pavement materials (if any) whose layer thicknesses are required and, when sound cemented material is present, if an estimate of its stiffness is required. Further, for each Existing Pavement Type and proposed Overlay Type, the same table indicates the data required from the deflection survey (including asphalt temperature for asphalt-surfaced pavements) and a specific reference to that Section of Appendix J in the Interim Release of the overlay revision (AUSTROADS, 1994) which provides a step-by-step procedure for the specific design situation.

A deflection survey is then undertaken to acquire the relevant deflection data, together with temperature measurements of the asphalt surface (if present).

Estimate levels of sub-grade and cemented material critical strain at measurement temperature

The designer then turns to that Section of Appendix J of the Interim Release, for the specific Existing Pavement Type and Proposed Overlay Type and determines, from the equations provided, the levels of sub-grade and cemented material critical strains in the existing pavement when the asphalt temperature is that measured. Substitution in the equations of the appropriate deflection bowl values and material thicknesses allows the strain levels to be calculated.

Estimate critical strain levels and deflection bowl parameters at WMAPT

These strain levels together with the CF and D_{900} values at the measurement temperature are then adjusted to levels at the WMAPT by selecting the WMAPT for the locality from Appendix C of the Pavement Design Guide (AUSTROADS, 1992) and using the relationships in the appropriate section of Appendix J of the Interim Release. Substituting values of the relevant parameters in the equations provided gives the levels of sub-grade strain, cemented material strain, CF and D_{900} in the pavement at its operating temperature (WMAPT).

Estimate appropriate levels of critical strain

The appropriate levels of critical strains for the design period are obtained by first determining, for each critical strain, the number of repetitions of a Standard Axle which will cause the same level of distress as the design traffic (ESAs) (Section 7.5 of the AUSTROADS Guide). Using the appropriate performance relationships (sub-grade - Section 5.9, asphalt - Section 6.4.6, cemented materials - Section 6.3.4 of the Guide) together with the Standard Axle repetitions, the appropriate levels of critical strain are determined.

Determine overlay thicknesses to achieve appropriate sub-grade and cemented material strains

For each relevant critical strain, the overlay thickness needed to reduce the level from that in the existing pavement to the appropriate level is determined by substituting the appropriate parameter values in the relationship provided in the relevant section of Appendix J of the Interim Release.

Determine overlay thicknesses to protect asphalt surfacing

A TRIAL thickness of asphalt overlay is selected and corresponding TRIAL values of CF and D_{900} are determined by substituting in the appropriate equations provided in the relevant section of Appendix J of the Interim Release. The level of asphalt strain associated with the trial overlay thickness is determined by substituting the trial CF and D_{900} values in the relationship provided in the Appendix. This asphalt strain level is compared with the design level and, provided it is less than the design level, the trial thickness is satisfactory. Otherwise, a new trial thickness is chosen and the process repeated. This is continued until a satisfactory thickness is determined.

Determine design overlay thickness

The required overlay thickness is the largest of the thicknesses required for each of the relevant critical strains.

6. Concrete Overlays On Existing Flexible Pavements

A concrete overlay is designed in the same way as a new concrete pavement, using the existing flexible pavement as a sub-base. Depending on the structure and materials in the existing pavement and the type of concrete overlay to be placed on it, the existing pavement may require modification or additional material to provide an adequate sub-base for the concrete overlay.

The design method is similar to that for a new rigid pavement as set out in Section 9 of the Pavement Design Guide (AUSTROADS, 1992). The existing flexible pavement materials, other than those which satisfy (in part or totally) the requirements for a bound sub-base, are considered part of the sub-grade. The Interim Release of the overlay revision provides two methods (both of which utilise a graphical relationship between CBR and measured deflections) of estimating the design sub-grade CBR, depending upon whether there is or is not suitable bound material at the surface of the existing pavement.

Where the surface layer of the existing pavement includes material which either meets the requirements of bound sub-base materials with a minimum asphalt modulus of 2000 MPa at 25^{o}C determined from back-calculation of measured deflection bowls, or can be stabilised to meet these requirements, it may form all or part of the minimum sub-base requirements.

The existing pavement may be improved to meet the recommended thickness for a bound sub-base either by cement stabilisation of the existing pavement (if the material is suitable), by adding a correcting layer of dense graded asphalt to an existing asphalt surface, or by constructing a new sub-base. Where the existing pavement has been improved in any of these ways, the design sub-grade CBR is the value assigned to the material below the improved pavement layer.

Having satisfied the minimum sub-base requirements and determined an effective CBR, the designer follows the procedure for the design of rigid pavements provided in Chapter 9 of the Pavement Design guide (AUSTROADS, 1992).

7. Asphalt Overlays On Existing Rigid Pavements

The predominant distress mode for asphalt overlays on concrete pavements is the development of cracks in the asphalt directly above cracks and joints in the underlying concrete pavement.

The overlay design procedure aims at containing the development of these reflection cracks to an acceptable level by both limiting the allowable mean and differential deflections at joints and cracks and requiring thicker overlays where thermal expansion and contraction of the concrete slabs is more severe.

To meet the deflection limiting criteria, Benkelman Beam deflection testing is carried out along the outer edge of the outer lane at the location of transverse joints and cracks. Maximum deflection measurements are taken for two passes of the truck in the outer lane, with the beam tip being changed from one side of the joint/crack to the other between passes. The differential deflection is the difference between the two measured deflections and the mean deflection is their mean. The recommended overlay thickness to protect against load-induced reflection cracking is then that required to reduce the measured values of mean and differential deflections to tolerable levels of 0.36 and 0.05mm respectively, deflection reductions being calculated on the basis of 1% reduction per 5mm of overlay thickness.

For the thermal expansion/contraction criterion, a "temperature differential" is calculated as the difference between the highest monthly average maximum and the lowest monthly average minimum daily temperatures for the Bureau of Meteorology recording station nearest to the site. A tabulation of required overlay thickness against the temperature differential and slab length is then consulted.

The required overlay thickness is the greater of the thickness to protect against thermal movements and that to protect against load movements.

8. Concrete Overlays On Existing Rigid Pavements

The design of concrete overlays on concrete pavements is based on methods originally developed by the US Army Corps of Engineers (1988) and subsequently extended by the Portland Cement Association of the USA (Tayabji and Okamoto, 1985). The design equations include four variables:

- t_n the thickness (mm) of concrete base which would be required if placed directly on the sub-base/sub-grade beneath the existing concrete base;
- t_e the thickness (mm) of the existing concrete base after certain adjustments;
- t_o the thickness (mm) of concrete overlay; and
- C condition coefficient of the existing concrete base.

Three types of concrete overlay are considered, according to whether the overlay is fully bonded, partially bonded or unbonded to the existing concrete pavement surface. For each type of overlay, the overlay thickness is calculated as

$$t_o = (t_n^x - C.t_e^x)^{1/x}$$

where
- $x = 1$ and $C = 1$ for fully bonded overlays,
- $x = 1.4$ and C varies for partially bonded overlays, and
- $x = 2$ and C varies for unbonded overlays.

The condition coefficient C takes the value 1 if the existing pavement is in good overall condition and exhibits no cracking, and it is only in this case that a fully bonded overlay can be applied. Lower values of C are defined corresponding to poorer conditions of the existing pavement, for which either partially bonded or unbonded overlays may be applied.

A number of practical issues must be taken into account in the design of concrete overlays on rigid pavements. These include proper assessment of existing pavements, consideration of the effects of concrete shoulders, vertical matching of existing pavement and overlay joints, requirements to achieve full bonding, and practical minimum overlay thicknesses.

9. Summary

Procedures for design of pavement overlays, consistent with those employed in the design of new pavements, have been developed on behalf of AUSTROADS and have been released to the profession for comment. These procedures cover the design of flexible overlays (granular, asphalt or mixed material) or concrete overlays on existing flexible pavements, and the design of asphalt or concrete overlays on existing rigid pavements. This paper has provided a brief overview of the procedures for each of these design situations.

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Mix Characteristics and Field Performance of Asphalt

by

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1. Introduction

Stripping in asphalt can be defined in several ways depending on the type of action between the various components of the mix and water. It may be caused by the displacement of binder film from the aggregate surface resulting in a loss of adhesion, or by the softening of the binder resulting in a loss of cohesion. A further form of stripping is a cohesive failure near the surface within the aggregate.

Stripping can be caused by many factors ranging from characteristics of raw materials, environment, traffic and construction practice and can occur at any level in the asphalt pavement.

Stripping always occurs in the presence of water and is accelerated by environments of high temperatures and heavy traffic loading.

2. Background

The asphalt industry (worldwide) has been aware of the phenomenon of stripping for many years and there are documented proven methods of minimising the risk of stripping in an asphalt pavement.

The Australian Asphalt Pavement Association (AAPA) and the Roads and Traffic Authority (RTA) agree that asphalt in heavy duty pavements has not performed up to expectation in recent years in regard to rutting and stripping. Of particular concern was the unexpected extent of stripping which had occurred on heavy duty asphalt pavements.

Discussions have been held between the parties in an effort to improve the situation and there is currently an investigation being conducted on in-situ asphalts with the aim of identifying solutions to the problem.

The Authority's current asphalt specifications do not directly address all the factors which can contribute to or cause stripping.

3. Water Damage to Asphalt

Although the role of water in stripping is not entirely understood, there are thought to be as many as five mechanisms by which stripping may occur. These include detachment, displacement, spontaneous emulsification, pore pressure and hydraulic scouring (1). In terms of observed response, water damage of asphalt may be manifested in three ways;

1. The bitumen binder interacts with water resulting in a reduction in cohesion within the binder with an associated reduction in the stiffness and strength of the mix (2).

   The mechanism is thought to be the development of an inverted emulsion where water droplets are suspended in the bitumen, thus reducing its stiffness.

2. The water works its way between the binder film and the aggregate surface causing the adhesive bond to break and thus 'strip' the binder from the aggregate (2).

3. The surface of the aggregate to which the binder has initially adhered loses integrity (or even partly dissolves) as the water infiltrates thus causing a loss of bond.

While these stripping actions may occur separately, they are related because stripping damage may be a result of a combination the above.

4. Modes of Asphalt Stripping Failure

Stripping can result in any of the typical distress signs of an asphalt pavement such as:

Potholing The most predominant symptom of stripping.

Rutting Due to stripping in a much lower layer in the pavement.

ShovingDue to low wet strength (Early stage of potholing).

Cracking Due to low strength

The typical early signs can begin with wet patches and slight dish shaped depressions in the asphalt surface. The next stage is the appearance of fines around the depressions (possibly stripped filler, dehydrated water soluble salts or rock powder from coarse aggregate rubbing together). At about this stage, fatty areas of migrating (or displaced) binder appear in the surface and a small pothole becomes apparent (3).

The dish shaped depressions often occur at regular intervals (possibly due to wheel bounce) and eventually the depressions tend to join up to become what appears to be a rough rut; the potholes become larger and the eventual result is widespread disintegration.

In contrast, a recent case of stripping on the Authority's roads exhibited symptoms of severe rutting only. A lower layer of asphalt had stripped badly but the upper layer was sufficiently flexible to follow the deformation with only minor cracking in the surface. The important point to be made here is that distress needs to be investigated thoroughly to determine the real cause of failure.

5. Factors Which Influence Stripping

There are many factors which can cause or contribute to stripping in an asphalt including pavement design, raw material characteristics, variability in process control and poor placing techniques.

The following notes briefly outline contemporary thinking on some of the more common of these factors.

5.1 Aggregate

It is known that the physical and chemical composition of aggregate influences its affinity for water. The adhesion properties and tendency to strip cannot simply be related to the generic type of aggregate. Aggregates may be classified as either hydrophilic or hydrophobic with the former considered to be of acidic chemical nature and the latter to be of basic chemical nature (1).

Generally, hydrophobic aggregates provide better resistance to stripping of binder film than do hydrophilic aggregates although this is not always the case. Few if any aggregates can completely resist the stripping mechanism of water (1).

Aggregates should be selected on the basis of cleanliness, moisture content, chemical composition, physical characteristics, and resistance to degradation.

In regard to stripping, typical considerations are as follows,

Cleanliness of the aggregate is essential to allow close contact between the aggregate surface and the binder. Coating binder over a layer of dust or clay is unacceptable because binder will not adhere to aggregate particles that are coated in dust. Dust creates small holes in the binder coating which provide access for water to the binder surface (4). It cannot be assumed that such coatings of dust will be dislodged in the drying drum. Excessive dust on the feed can result in a high filler/binder ratio and possibly 'ball up' the binder in the mix before it has time to properly coat the aggregate. Washing of aggregates may need to be considered in some cases.

Aggregates must be *dry* when initially coated with binder and it is advisable to check the temperatures and production rate at which drum mixers are being operated, particularly at periods of high production.

Aggregates with *high pH* are preferred as binder is considered to be slightly acidic. Polarity of the major molecular components can be adjusted by the addition of other compatible polar materials such as adhesion agents but this is not the preferred option as the long term life of these agents is uncertain. Suitable reactive materials such as hydrated lime filler can also act to enhance polar bonding (4).

Aggregates with *coarse surface texture* promote better physical connection between the binder and aggregate surface because the binder penetrates the pores and microcracks of the aggregate (1). *Low porosity* is also an important characteristic as binders (or their lighter components) can continue to be absorbed in service eventually resulting in a situation conducive to stripping. The water absorption test can be used as an indicator of porosity.

Aggregate surfaces should be *sound* as those with high concentrations of components which develop into water soluble salts generally suffer a cohesive failure in the aggregate within the zone where binder has penetrated the porous subsurface. Although this mechanism is not strictly displacement of the binder from the surface by water, it is now considered to be one of the major factors contributing to failure and the end result appears the same as for normal stripping. Typical examples would be calcareous limestones and those aggregates rich in alkali-metal elements especially if freshly crushed (5).

An asphalt produced with a freshly crushed aggregate may have poor resistance to stripping when compared to the same aggregate that has been stockpiled for some time. Following aging of some crushed aggregates, the outermost water molecules adsorbed on the aggregate surface may be replaced or covered by organic contaminants present in air such as fatty acids and oils. It is thought that this contamination process may be the reason for the better stripping resistance of aged or weathered aggregate over that of the same aggregate which is freshly crushed (1).

The properties of fine aggregates and fillers are just as critical to stripping as those of coarse aggregates because the fine aggregate forms the basic matrix of the mixture (3). Despite this, there is currently very little testing, if any, on these fractions. For example, the presence of clay in natural fine aggregates and fillers can make the mix particularly water susceptible.

It should be noted that it is not always the high quality portions of the stone which break down into the fine particles during crushing. The fine particles may be of lower strength than the coarse particles or contain deleterious materials. Thus, it cannot be assumed that the fine particles are necessarily similar in nature to the coarse particles.

5.2 Binder

Binder film thickness and viscosity are the major considerations from the point of view of stripping. The stiffer the binder, the more difficult it is to dislodge it from the aggregate surface and the thicker the film, the more difficult it is for the water to penetrate through to the aggregate surface. However, during the mixing process, low viscosity is desirable in a binder because it has more wetting power than one of high viscosity (1).

Currently, the Authority's binder specifications are only based on physical properties such as viscosity and consistency even though chemical composition is also noted to influence stripping (2). Furthermore, it appears that there is limited control over the chemical consistency of the source crude and very little chemical type testing done on binders in this country by manufacturers. This apparent deficiency is currently being followed up.

5.3 Binder Adhesion Agents

Liquid Adhesion Agents

Liquid adhesion agents are cationic surfactants and are otherwise known as 'wetting agents' or 'anti-stripping agents'. They improve the wetting of aggregate by binder by decreasing the surface tension at component surfaces. The adhesion between binder and aggregate is also improved and this is associated with the binder being given an electrical charge that is often opposite to that of the aggregate (2).

Most cationic surfactants are not heat stable indefinitely and degrade at a rate which depends on temperature, the chemical type of adhesion agent and the binder. Once the bituminous product has been placed, the ongoing life of the adhesion agent is uncertain (6).

Adhesion agents are not emulsifying agents but emulsifying agents are manufactured by reacting adhesion agents with acid. Thus, in high acid content bitumens, there can be a slow degradation of the adhesion agent. It should be noted that currently in Australia, bitumens have generally been considered on average to be low in acid content.

The effectiveness and appropriate quantity of an adhesion agent will depend on the combination of mix components and should be evaluated for each application by a stripping test carried out on the asphalt production mix. Particular care must be taken in practice to ensure adequate mixing of relatively small quantities of adhesion agents throughout large quantities of binder.

Hydrated Lime

The use of hydrated lime in asphalt improves resistance to stripping and increases the stiffness of the mix (7).

The action of the hydrated lime has not yet been fully explained but the following mechanisms have been suggested (2 & 8),

> Formation of less soluble ions at the aggregate surface (Calcium replaces hydrogen, sodium and potassium).
>
> Interacts with carboxylic acids in the binder to form insoluble salts at the surface of the aggregate.
>
> Sharp decrease in interfacial tension between binder and water to improve wetting and promote better adhesion.

Hydrated lime is most effective when applied to the aggregate surface as a lime slurry prior to mixing, but in Australia, it is normally introduced as a filler and dry mixed with the aggregate in the manufacturing process.

Limestone Dust

The Authority does not accept limestone dust as an equivalent to hydrated lime. Limestone is a carbonated form of lime and in that state is much less reactive than hydrated lime.

Limestone dust has traditionally had low dry compacted air voids and thus its stiffening effect on the mix is much less than for hydrated lime.

5.4 Mix design

It has been found that the potential for stripping of an asphalt is related to the mix design characteristics and to the application of the mix. Dense graded mixes, asphalt base courses and surfacing courses may experience problems with stripping in the case of excessive air voids, insufficient binder, inadequate compaction or moist or dusty aggregate (1). The high permeability in open graded mixes would normally be expected to make them more vulnerable to water damage but this can be offset in practice by increased binder film thickness.

Constituent Ratios

Attention must also be given to the ratio of fines (material passing 0.075mm sieve) to binder as the presence of excessive fines or low binder content or both can lead to stripping and pavement distress (9).

American literature recommends a ratio of fines to binder in the range of 0.6 to 1.2 by mass (9), however, this range is presently being evaluated for applicability to Australian practice and conditions. In practical terms, if this ratio is too high, the durability of the mix will be adversely affected because of a lack of a sufficient quantity of binder. If the ratio is too low, this represents an excess of binder which may lead to problems with stability of the mix (10).

Effect of Fillers

An excessive amount of filler reduces the availability of voids in the mineral aggregate (VMA) to allow a sufficient quantity of bitumen to be added for durability. It also increases the surface area of aggregate to be coated with binder which results in a reduction in binder film thickness (10).

It has been shown that the chemical nature of different types of filler can affect the reaction with binder and the susceptibility of the mix to stripping (11). Depending on the type of filler, the amount of binder required to prevent water damage of a mix may be in excess of that required to achieve stability of the mix. In this case, an obvious incompatibility between materials and application is apparent and that combination may have to be discarded.

The new RTA asphalt specification seeks to address the issues of chemical compatibility and volumetric control of all the material passing the 0.075mm sieve whereas the present specification addresses only imported fillers.

5.5 Asphalt Production

Raw material feed must be strictly controlled particularly in regard to consistency of source and quality of materials. For instance, aggregate supplies are often variable in terms of composition, cleanliness and grading.

Heating and Drying

The wettability of an aggregate is improved if the aggregate is thoroughly dry before mixing. Hot aggregate also promotes adhesion of the binder by reducing its viscosity on contact with the aggregate. Wet aggregate should be dried at temperatures above 100^{o}C which then facilitates the ready removal of water as steam (4). Even though the surface temperature of the aggregate may be well above 100^{o}C, there may still be moisture present within the aggregate which has not evaporated because of the relatively short cycle time for drying. This moisture may eventually find its way to the surface of the aggregate when it is part of the asphalt mix.

With moist or wet aggregate feeds there needs to be more heat energy available per tonne of aggregate than for dry aggregate but surface temperatures should not then be so high that the binder is damaged on contact with a superheated aggregate. If it is not practical to increase heat input, the rate of aggregate feed may need to be reduced.

Mixing Time

Small changes in mixing time per production cycle can represent a significant amount of time over the course of a production run. However, it should be emphasised that the time allowed for mixing of binder with aggregate cannot be continually reduced without compromising the quality and quantity of binder coating which the aggregate receives.

The stiffness of binders is also important in the mixing process. Occupational Health and Safety requirements may place limitations on mixing temperature yet the viscosity still has to be low enough for the binder to properly coat the aggregate. In general, mixing times for stiffer binders need to be increased over those for standard binders.

Binders produced by different refining processes currently heat harden to different rates during subsequent processing (including haulage) and, again, the adequacy of mixing time needs to be considered.

5.6 Asphalt Placement

Two of the most important factors in the placement of asphalt are the uniformity of the mix as it is laid (prevention of segregation) and achieving adequate compaction prior to opening the pavement to traffic. These factors are related in that adequate compaction cannot be achieved if the mix is segregated and it follows that the mix will not perform as required in terms of stiffness, strength or durability. Aggregates tending to have good shape and grading will result in less segregation and better compaction of the mix with a resultant reduction in permeability.

In-situ Air Voids

Proper compaction is necessary to ensure that the in-situ air voids content is within the specified range. It has been hypothesised (2) that there is an air voids content below which the voids in the compacted asphalt mixture are not connected and thus do not allow entry or passage to water, that is, the mix is effectively impermeable. Conversely, there is an air voids content above which the voids are connected and allow free entry and drainage of water through the asphalt mix, such as the case of an open-graded asphalt.

The region in between these low and high voids contents is known as the "pessimum voids" content and is characterised by an asphalt mix that is neither impermeable nor free draining. The practical consequence of an asphalt mix with a voids content within this range is one which allows entry of water which is then trapped within the asphalt structure, with the likelihood of stripping occurring. The pessimum voids content is considered to be generally in the range of 8 to 14% (2).

Densification Under Traffic

Where an asphalt pavement is constructed with air voids above the design air voids range with allowance for traffic to lower the air voids over a number of years, the risk of exposing the pavement to stripping distress and failure is increased. Experience has shown that stripping failure of a pavement can occur within 6 months of construction.

In allowing for traffic to increase the density of the pavement, the upper and lower range of the specified air voids content should be observed so that, following construction, the air voids content is no higher than the upper limit and does not fall below the lower limit with trafficking.

5.7 Weather Conditions

Pavements which are constructed with asphalt in weather conditions which are cool and wet are more susceptible to stripping. This is also the case if rain immediately follows a paving operation because the viscosity of the bitumen remains relatively low for several hours after paving (1). As was stated earlier, a bitumen of low viscosity is less resistant to water damage than a bitumen of higher viscosity.

5.8 Pavement Design

Two critical factors in designing a pavement to prevent stripping are pavement drainage and suitable layering for different types of asphalt mixes or pavement seals (9).

The designer should be aware of the following stripping mechanisms:

> In some cases, stripping begins in the bottom of an asphalt pavement which rests on a wet granular base and works its way up through the pavement. In this case, the failure is a result of the normal water damage mechanisms.
>
> Stripping has occurred in the bottom of an asphalt pavement which rests on a granular base which is essentially dry but only occasionally becomes wet. In this case, the actual

stripping failure results from water damage but the asphalt has been made more susceptible by the light oils from the binder having been absorbed into the base materials during hot dry periods (similar to the effect where these oils are absorbed into porous aggregates).

Stripping has been observed in one or more layers of asphalt which forms part of the asphalt pavement. Water accumulates in the asphalt pavement (either from above or below) because of disjointed permeability and stripping occurs.

Subsurface Drainage

The effectiveness of subsurface drainage on wide pavements must be carefully considered not only in terms of installation of drainage facilities such as slotted conduits and fabrics but also in terms of longitudinal and lateral flow paths particularly where this is influenced by superelevation. That is, the flow path may be such that water does not reach drainage facilities which are typically placed along the edges of a pavement.

The lateral movement of water through wide pavements on relatively flat grades is relatively slow and it has been suggested that in this case the most common movement of water is upward by capillary action to a point where it moves as vapour. This problem can be made worse when pavements are widened prior to overlay without provision of additional subsurface drainage (3).

In the case where a sprayed seal is applied below an open graded surfacing, it is imperative that effective longitudinal and lateral subsurface drainage is provided to remove the water from within the pavement as quickly as possible.

Pavement Layering and Seal Coats

In cases where subsurface drainage is effective but there is still some doubt about the ability of the asphalt to resist stripping, the pavement designer must consider options to prevent entry of water into the asphalt pavement. Such options may include:

Use of a sprayed seal just below an open grade surfacing.

Use of larger nominal size of asphalts in lower layers and smaller nominal size asphalts in surface layers. In multi layer work, nominal size should gradually decrease layer by layer in the direction of the surface.

It is acknowledged that many existing pavements may have inadequate or ineffective subsurface drainage. Designs in these cases should be based on an assessed balance of risk.

To minimise the effect of damage induced by lighter fractions of the binder being absorbed into the base (nominally observed to occur more over cement or lime treated bases), the following options should be considered.

Use of a primer seal to enrich the lower surface of the asphalt layer.

In appropriate cases, use of a bitumen rich anti-fatigue layer of asphalt in contact with the base. In such cases, the extent of cover over the bitumen rich layer will need to be sufficient to ensure stability of the asphalt pavement.

Finally, it should be noted that layers of pavement fabric also cause disjointed permeability similar to a seal coat.

6 Stripping Tests

The effectiveness of a stripping test is heavily reliant on the sample preparation and conditioning procedure. The three most common types of stripping test and sample conditioning methods currently available are:

Immersion in hot or boiling water with a view to detecting dislodged binder or aggregate particles (eg. bitumen stains on the surface of a glass beaker). Sample conditioning is minimal and either loose or compacted material can be used.

Loss of stiffness or tensile strength in a partially saturated sample compared to a dry sample. Compacted samples are used and these are usually soaked or vacuum saturated and may also be subjected to freeze/thaw conditioning.

Loss of strength in an immersed sample under repeated loading (eg. rolling wheel). Sample preparation is usually similar to that in the paragraph above.

Stripping tests such as the boiling tests are effective in identifying very poor material combinations but fail to have good overall correlation to field performance. The test having the best overall correlation to field performance is a modified Lottman type test which involves measurement of the tensile strength ratio of moisture conditioned specimens compared to dry specimens.

Existing RTA Stripping Tests

In regard to stripping tests, the Authority's asphalt specifications specify conformance to the plate stripping test T230 which is a fundamental test for adhesion of the coarse aggregate to the binder. This test was originally developed for use in connection with sprayed seal work and its effectiveness as the sole stripping test in respect of asphalt has been questioned as there are known to be many other factors which can influence stripping.

New RTA Stripping Test

The Authority had previously recognised the limitations of Test T230 and commissioned a report from a consultant on a more effective test. Based on this report, Pavements Branch commenced development work in early 1994 on the adaptation of a modified version of the Lottman (12) type test. The Authority's version of this test is identified as T640 (Draft). The test is presently being evaluated for precision and performance with various types of asphalt mixes.

It was also recognised at an early stage that the test would need to be applied to production mix sampled as late as possible in the process in order to include as many variables as possible. Laboratory mixes have generally been found not to replicate production mixes in regard to stripping. This is possibly due to differences in mixing times and techniques and could also be due to a greater control of constituent materials which is inherent in a laboratory process and not usually duplicated in a field production environment.

Test Method T640 (Draft) can be briefly described as follows,

Test Method T640 (Draft) sets out the procedures for preparation of specimens and measurement of the change of indirect tensile strength resulting from the effects of saturation and accelerated moisture conditioning. The procedures have been adapted from American standards ASTM 4867-92 and AASHTO T283-85.

Specimens are prepared from a dense graded bituminous mix to an air voids content in the range of 7 to 9% from mixes derived from either laboratory or production mix. This air voids content is within the pessimum range as described earlier. It is essential to allow entry of water into, but to prevent free drainage of water from, the specimen.

The specimens are divided into two subsets of approximately equal voids content. One subset is conditioned by being partially saturated with water in the range of 55 to 80% followed by one cycle of freezing and thawing while the other subset is conditioned in a dry state. If the saturation of the specimen exceeds 80%, the specimen is presumed to have been damaged and must be discarded. Replacement specimens must then be produced.

The tensile strength of each specimen within a subset is determined by the tensile splitting test. The potential for damage by moisture is indicated by the ratio of the tensile strength of the moisture conditioned subset to that of the dry subset. The testing machine used to split the specimens in the Authority's Milsons Point asphalt laboratory is that used for

Marshall/Hubbard-Field testing, set to Marshall testing mode. However, other types of apparatus which satisfy T640 (Draft) may also be used.

The effect of a change to a variable within the mix such as a change in the type of binder, filler or aggregate, or the addition of an adhesion agent, among others, may be determined by preparing moisture conditioned specimens and testing as described above. The effect of the change to the variable may be indicated by the ratio of the tensile strength of the moisture conditioned subset to the tensile strength of the control dry subset.

The inclusion of one freeze/thaw cycle in the test is meant to portray stress which the components of the asphalt may sustain in the long term (13). It is not intended to imitate weather conditions as such for this would require many freeze/thaw cycles to represent several seasons over the life of the asphalt pavement.

The test does not rely on sophisticated equipment of the type which would not commonly be available in an asphalt laboratory and is approximately 2.5 days in duration (most of the time required for the test is taken up with conditioning of the specimens in various temperature environments and total operator time is typically 7 to 8 hours).

The acceptance criteria proposed for the Authority's specification is a minimum of 80% tensile strength ratio which is based on American research (14) and limited in-house testing of laboratory and production mixes.

One of the major advantages of using tensile strength instead of resilient modulus is the ability to view the split faces of the sample for evidence of stripping. Producers and contract administrators are strongly encouraged to take advantage of this feature.

The T640 (Draft) test is also a very useful design tool in that producers are able to adjust one mix variable at a time to determine its effect and degree of sensitivity on stripping of the mix.

7 Addressing the Current Stripping Problem

In the latter part of 1994, serious concerns were raised by Authority field personnel regarding poor asphalt performance which led to the matter being raised with AAPA in January 1995.

The Asphalt Industry conducted its own investigation and convened a meeting of National Technical Managers in Yass late the following February. Authority Representatives attended the meeting and a strategy to address the current stripping problem was formulated.

The following action was proposed in order to minimise the immediate risk:

Specification changes directly focussed on stripping in heavy duty asphalt pavements. These changes were tabled by the Authority in March 1994 and their introduction is currently being negotiated. It appears at this stage that Specification R47 will only be selectively amended and that a new specification for heavy duty asphalt will be introduced.

Publication of Guidelines for adoption by Industry. A draft has been prepared by the National Technical Manager of AAPA and is currently being reviewed by interested parties. It is understood that these guidelines were scheduled for publication at the end of April 1995.

Possible *treatments for distressed pavements* were discussed, with the final decision regarding treatment resting with the local RTA Zone. A variety of treatments have already been adopted including heavy asphalt patching, sprayed seals and in-situ recycling.

Sampling and investigation of the stripped pavements is also under way based on a pilot program conducted by Wollongong Zone. Data which are presently being collected from Authority and Industry testing programs will be combined with contract test data in a small database in Pavements Branch for analysis. A report is expected to be published in August 1995.

Training in regard to cause and prevention of stripping is to be conducted through forums such as the Authority's Technology Transfer Workshops and Industry Training Courses.

8 Considerations for the Future

The outlook is positive with Industry agreeing that there is a need to improve the performance of asphalt and stating their commitment to working with the RTA in developing short term solutions to improve performance and to the longer term goal of providing products on a performance basis.

Authority pavement designers and service providers will need to remain aware of the risks associated with inadequate designs and poor construction practice and play a pro-active role in making sure that the risk of stripping in asphalt is minimised in future.

Premature failure of asphalt should always be immediately reported to the Authority's Pavements Branch or Engineering Contracts Branch.

Contract Administrators should ensure that quality records continue to be available to Pavements Branch for the full period defined in the contract (usually 5 years from issue of final certificate).

9 References

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13. Maupin G.W. Jr., "Implementation of Stripping Test for Asphaltic Concrete", Transportation Research Record 712, Transportation Research Board, National Research Council, Washington, D.C. (1979) pp8-12.

14. Stuart K.D., "Evaluation of Procedures used to Predict Moisture Damage in Asphalt Mixtures", U.S. Department of Transportation, Federal Highway Administration Report FHWA/RD-86/091, Final Report, March 1986.

Sprayed Sealing Update

by

Ray Gaughan
RTA Technology

1. INTRODUCTION

The purpose of this paper is to provide participants with an overview of the state-of-theart of sprayed sealing technology and inform practitioners of current and ongoing developments in sprayed sealing. Sprayed seal design; bitumens, polymer modified bitumens (PMB), bitumen emulsions and foamed bitumen binders; aggregate application; precoating; geotextile reinforced seals, fibre reinforced seals and slurry surfacings are discussed.

During recent years there has been a significant increase in the number of sealing systems and techniques being offered to the road practitioner. To encourage the use of new products and innovations a number of RTA Guides have been produced and issued. When the treatments have been evaluated by Pavements Branch, their use will be included in subsequent editions of the RTA Sprayed Sealing Guide.

2. GENERAL

Irrespective of the type of treatment presented hereunder, it is important to recognise that all treatments form part of the pavement and each must comply with the overall design requirements. Preliminary pavement preparation is therefore vital to the achievement of the desired performance.

3. SPRAYED SEAL DESIGN

For the past three years the AUSTROADS National Bituminous Surfacings Research Group (NBSRG) has conducted sprayed seal field trials in New South Wales, Victoria, South Australia and Western Australia with the intention of evaluating and improving the current AUSTROADS Spray Seal Design Method. The results of this study are currently being collated and evaluated and will be used to update the current method. It is anticipated that the updated design method will be issued before December, 1995.

Experience has shown that, no matter how good, any seal design method that produces a "single" design binder and aggregate application rate for a particular location will not be readily accepted Australia wide without local modifications. Consequently, the AUSTROADS Sprayed Sealing Group intends to issue a method which produces a range of application rates for both binder and aggregate/s together with recommendations regarding their use.

To ensure objectivity in assessing the existing surface characteristics and determining the appropriate allowances to be made for the design, a manual of test methods will be issued to support design method. A second manual of test methods will also be issued to assist the practitioner with local seal investigation and long term monitoring.

Other areas of sealing including sprayer calibration, standard hose connections, aggregate spreading and rolling, cutter charts and monitoring strategies are also under investigation and the results will be published as guides.

4. BITUMEN

General

Class 170 bitumen is the most commonly used sprayed sealing binder in New South Wales. In some instances, Class 320 bitumen may be used. The rationale for using Class 320 bitumen is that it is stiffer at higher temperatures and hence less likely to bleed. In actual fact, the difference in softening point of the two classes of bitumen is only about 4 to 5°C and therefore any seal defect is more likely to result from incorrect design or operational procedures.

During the past ten years, if a less temperature susceptible sealing binder was required, a polymer modified bitumen could be used (at an increased initial cost) to overcome the problem if this was considered to be a cost effective solution.

Multigrade Bitumen

The most recent innovation in the area of bitumen binders is "Multigrade" bitumen which is a bitumen with properties spanning 2 or 3 of present AS grades. This type of bitumen is designed to perform over a range of conventional AS 2008 Grades and be stiffer at higher temperatures and softer at lower temperatures. Multigrade bitumen is less temperature susceptible than conventional C170 or C320 bitumens and for a slight increase in cost may be used and handled in the same manner as conventional bitumen.

Multigrade bitumen binders have been used successfully in asphalt work for the last 12 months. A sprayed sealing Multigrade bitumen is currently being trialled in Queensland, NSW, Victoria and South Australia in various sealing applications. It is expected that the inclusion of Multigrade will increase the range of sealing binders available to the sealing practitioner.

5. POLYMER MODIFIED BITUMEN (PMB)

General

In 1992, the AUSTROADS PMB Project Group summarised available information on PMBs in the form of APRG Report No.7, Part 4. This document includes synthetic polymer and scrap rubber modified bitumens under the umbrella of "polymer modified binders". Subsequently, a number of additional PMBs have become available and an AUSTROADS trial is currently being undertaken in Queensland to evaluate and rank the broad polymer types in terms of ability to delay or prevent reflective cracking when applied in Strain Alleviating Membrane (SAM) applications.
Polymer modified bitumen have a restricted storage time after mixing before degradation and this should be checked for each modifier.

Specification

The current specification for PMBs is RTA 3252, Edition 6, which includes four sealing grades, viz. S 1 to S4, and three asphalt grades, viz. A 1 to A3.
Specifications Parts R46 & R48 are presently being revised to incorporate the new RTA 3252 PMB grades and classes.

6. BITUMEN EMULSIONS

General

Over the past five years a great deal of work has been undertaken by the AUSTROADS Bitumen Emulsion Project Group to develop bitumen emulsion technology to meet the future needs of the road practitioner.

Areas of Development

- sealing in cold weather
- sealing in warm weather
- accelerated curing systems
- SAM and SAMI applications
- precoating agents
- dry matting maintenance technique
- primersealing
- compatability test for assessing bitumen emulsion primers and primerbinders.

7. AGGREGATE APPLICATION

General

Work undertaken by the RTA as part of the sprayed sealing review together with current AUSTROADS seal design trials has shown that, in the majority of instances, aggregate is overspread in sprayed sealing works. Due to the high cost of specialist self propelled aggregate spreaders, work is being carried out by the RTA and VicRoads to improve the accuracy of the cockerel spreaders which are currently used.

Seal behaviour studies show that aggregates in our seals are sitting at a height of about 1.5 of their Average Least Dimension (ALD) rather than on their ALD. This means that, at the time of sealing, aggregates are overspread to the extent that individual particles are prevented from rolling over and settling on their ALD. This has the following three very serious side effects:

(a) Invalidation of Design Method

Seal design methods are modelled to fit a number of assumptions. One reasonable assumption should therefore be "that the aggregate rolls over and sits on its ALD". When this does not occur in practice, then the method is invalidated and users either blame the method for any failures or start adding their own factors and variations to achieve their requirements.

(b) Reduced Efficiency and Economy

Aggregate which has been overspread is rarely recovered for re-use and is therefore wasted by brooming off to the side of the road. If less aggregate could be used to achieve an acceptable result, the process would be more efficient and economic.
Good sealing aggregates are becoming scarce and the fact that aggregate is a nonrenewable resource is not always appreciated.

(c) Potential Safety Hazard

The presence of loose aggregate on the road surface after sealing is always a potentia] safety hazard to motorists, i.e. it may result in broken windscreens, loss of tyre traction etc. If less aggregate was used, the potential risk would be reduced.

Current Practice

Cockerel spreaders are currently used for spreading aggregate during sealing due to their versatility and ease of use. Unfortunately, these spreaders are inaccurate and require very experienced operators.

New Development

A cooperative program is currently being undertaken by the RTA and VicRoads to improve the efficiency of cockerel spreaders. The intention is to improve the accuracy and economy of spreading to an acceptable level.

The latest prototype unit comprises a cockerel/roller spreader in which the roller speed is synchronised with the speed of the truck. These modifications appear to have achieved the desired improvement in the accuracy and mode of placing aggregate. This prototype has been purchased by the RTA and trials of the unit are currently being conducted by Pavements Branch in cooperation with the Bega District Office.

8. GEOTEXTILE REINFORCED SEALS

General

Geotextile reinforced seals have been successfully used in recent years as interlayers and all weather seals over clay pavements, and for waterproofing and strain alleviation applications.

Current Position

Geotextile reinforced seals are performing well in a diverse number of applications.
Issues To Be Resolved

As experience has been gained in the area of geotextile reinforced sealing technology, the following issues have arisen and need to be resolved.

- standard specifications
- polypropylene (melting point typically 165°C) versus polyester (melting point typically 250°C)
- laboratory test procedures
- permeability of geotextiles
- expected service life/performance
- construction and design guidelines
- material/treatment selection procedures
- appropriate/inappropriate uses
- maintenance/future rehabilitation
- recycling/environmental constraints

An R&D Project has been designed to address these issues in 1995/96.

9. FIBRE REINFORCED SEALS (FIBREDEC PROCESS)

General

Fibredec is a sprayed sealing treatment consisting of two coats of a polymer modified bituminous emulsion, between which is applied a layer of glass fibre strands. The fibres are applied in a random arrangement that resists reflective cracking. Finally, a layer of aggregate is spread and rolled in the normal manner. Under normal conditions, the surface may be opened to traffic immediately, as with conventional sprayed seals

As a wearing course, Fibredec provides a surface treatment which is resistant to cracking, i.e. a strain alleviating membrane (SAM). It may also be used as a strain alleviating membrane interlayer (SAMI) under other wearing courses.

Present Position

The Fibredec process has been used in NSW during the past two years. The present position is summarised below.

- performance and quality - variable
- majority of applications performing satisfactorily
- field trials over:
- black soil
- asphalt
- cement stabilised base
- existing cracked seal
- too early to gauge performance of Fibredec versus geotextile
- at least equivalent to polymer modified bitumen seal
- has potential environmental advantages

- easily applied

SLURRY SURFACING

General

Slurry surfacing is the general term referring to a stable suspension of emulsified bituminous binder (with or without a polymer modifier), graded mineral aggregate, mineral filler, additives and water properly proportioned to form a slurry which is spread evenly on the road surface. The type of slurry used, i.e. slurry seal or microsurfacing, depends on the proposed application.

Slurry seal is a thin layer of bituminous slurry surfacing, usually without a polymer modifier, and includes nominal size mixes up to Size 5 (5 mm).

Microsurfacing is a bituminous slurry surfacing, usually containing polymer, which is capable of being spread in variably thick layers for rut-filling and correction courses, and for wearing course applications where good surface texture is required to be maintained throughout the service life. It may include nominal mixes of Size 4 and larger.

Present Position

Slurry surfacing is currently used for improving surface characteristics, minor shape correction, seal widening, edge of seal correction and asphalt not an option (due to level restrictions).

Slurry surfacing is performing well in the dry western areas of NSW and in Council areas.

The level of performance of slurry surfacing depends on the following constraints which should be considered at the time of selecting this treatment:

- compatability with existing pavement
- preliminarypavementpreparation
- soundness of underlying pavement

REFERENCES

RTA Bituminous Slurry Surfacing Guide.

RTA Guide to the Use of the Novachip System of Bituminous Surfacing.

RTA Guide to the Use of Foamed Bitumen in Sprayed Sealing.
RTA Guide to the Use of the Fibredec System of Reinforced Bituminous Sprayed Sealing.

RTA Sprayed Sealing Guide.

With the proliferation of new products, in some cases, the importance of the "basics" of sealing practice has tended to be overlooked in the rush.

Appendix

Workshop Program

Wollongong Technology Transfer Workshop

R T A

Better Roads. Safer Roads. Saving Lives.

Date: Tuesday & Wednesday 2 & 3 May 1995
Time: 1330 to 1700 plus dinner 2 May 1995
0830 to 1630 3 May 1995
Venue: Novotel Northbeach
2-14 Cliff Road, Wollongong
Phone: (042) 26 3555 Fax: (042) 29 1705

Program Tuesday 2 May 1995

Time	Topic	Speaker	Topics
13.30 - 13.45	Welcome	Ulf Fraser *Director Southern Region*	
13.45 - 14.30	Electronic Data Location System	John Inglis *RTA Technology*	• What is EDLS? • Current applications • Applications in development
14.30 - 15.00	Electronic Warning at Road Construction Zones	Graham Brisbane *Wollongong Zone*	• Background to VMS signs • Known effects to date of VMS • Proposal for sign now developed
15.00 - 15.30	AFTERNOON TEA		
15.30 - 16.15	Performance Specified Maintenance Contract	Malcolm Frost *Infrastructure Maintenance*	• Reason for the contract approach • Background work • Pilot studies • Establishment of the first contract • Next steps
16.15 - 17.00	Road Network Video Capture	Michael Stanojevic *RTA Technology*	• System overview • Description
18.00	PRE-DINNER DRINKS		
	DINNER		

Program Wednesday 3 May 1995

Time	Topic	Speaker	Topics
08.30 - 08.45	Summary of First Day	René Burkart *Technology Strategy*	
08.45 - 09.30	Combined Girder and Deck Prefabricated Bridge Module	Tremayne West *RTA Technology*	• Reason for development • History of the module • Research and Development procedures • Expected outcomes • Technology Transfer
09.30 - 10.15	Raised Pavement Markers and Adhesives	Yogendra Bhatnagar *RTA Technology*	
10.15 - 10.45	MORNING TEA		
10.45 - 11.30	Flyash Pavement Field Trials	Gavin Donald *CERTS* Peter Kadar *CERTS* Chris Francis *RTA*	• Literature review of flyash in roads • Current field trials of stabilised flyash • ALF test for Eraring NSW • Proposed field trials with slipform paver • Benefits of flyash pavements
11.30 - 12.15	Concrete Paving Technology	Geoff Ayton *RTA Technology*	
12.15 - 13.15	LUNCH		
13.15 - 14.00	Overlay Design	David Bennett *ARRB*	• Introduction • Overlay design context • General mechanistic procedures • Simplified design procedure
14.00 - 14.45	Mix Characteristics and Field Performance of Asphalt	Greg Hall *RTA Technology*	• Stripping in asphalt
14.45 - 15.15	AFTERNOON TEA		
15.15 - 16.00	Sprayed Sealing Update	Ray Gaughan *RTA Technology*	• Seal design • Binders for sealing • Reinforced seals • Slurry surfacing • Aggregate spreading
16.00 - 16.30	Summary	René Burkart *Technology Strategy*	

Appendix

Workshop Attendance

Wollongong Technology Transfer Workshop
2 & 3 May 1995
Attendance Listing

First Name	Surname	Region
Ross	Abraham	Southern Region
Don	Arasakumar	Sydney
Geoff	Ayton	Pavement
Len	Baker	ARRB
Yogen	Bhatnagak	Traffic Technology
Mal	Bilawinskyj	Southern Region
John	Bodill	Southern Region
John	Booth	Northern Region
Graham	Brisbane	Southern Region
Val	Brizga	Southern Region
Rene	Burkart	Technology Strategy
Rod	Chapman	Southern Region
Terry	Clark	Sydney
David	Dash	RTA Technology
Ross	Dearden	Southern Region
Ian	Deck	Northern Region
Ron	DeRoy	Southern Region
Gavin	Donald	Representing CERTS
Wayne	Donaldson	Soutern Region
Maree	Edgley	CSR Readymix
Greg	Evans	Northern Region
Greg	Fell	Southern Region
Bruce	Fenton	ASMS
Ron	Ferguson	Technology Strategy
Chris	Francis	Northern Region
Ulf	Fraser	Southern Region
Malcolm	Frost	Infrastructure
Ray	Gaughan	RTA Technology
Srinivasan	Gopalakrishnan	Southern Region
Kali	Gupta	Southern Region
Greg	Hall	RTA Technology
Kevin	Hays	Northern Region
John	Inglis	RTA Technology
Peter	Jenkins	Northern Region
Henrik	Jurisevic	Pavements
Peter	Kadar	CERTS
Sa	Khegnyin	
T	Lal	VIP
Neil	Lamb	Southern Region
Ray	Lee	Southern Region
Ian	Long	Northern Region
Robyn	Lyster	Southern Region
John	McPhail	Southern Region

Peter	Meers	Southern Region
Dave	Mullens	Southern Region
Javier	Pena	Technology Strategy
Ian	Robinson	Southern Region
John	Ronczka	Technology Strategy
Michael	Standjevic	RTA Technology
John	Tasker	Southern Region
Mike	Veysey	Technology Strategy
Ross	Walsh	Sydney
Tremayne	West	RTA Technology
Glen	Weymer	Northern Region
Dick	Woodburn	Western Region

Notes