RTA

Research and Development Strategy Branch

Technology Transfer Workshop

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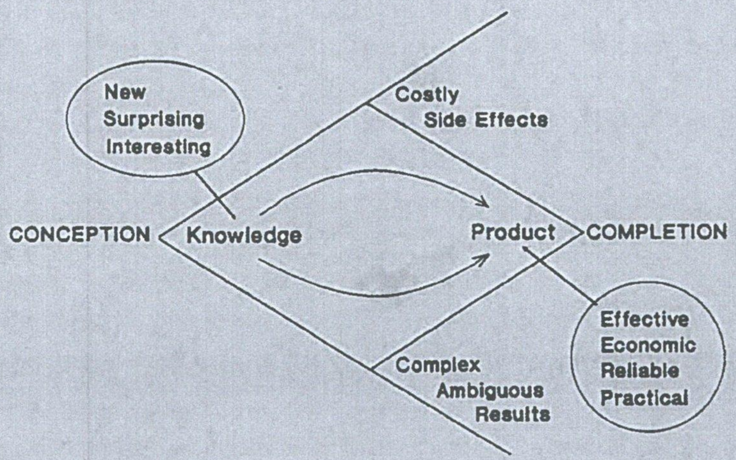
Summary Papers



CONTENTS

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Geotechnical Developments

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In this session dealing with Geotechnical matters the following R & D topics will be discussed:

1. Slope Stabilisation Using Soil Nailing
2. Rock Rippability
3. Satellite Imagery (ESIPP)
4. Geotechnically Useful Computer Programs
5. The Improved Ground Anchor Specification.

1. SLOPE STABILISATION USING SOIL NAILING

INTRODUCTION:

The Authority has successfully completed a major soil nailing project on the F3: Sydney to Newcastle Freeway at Mt White approximately 70 km north of Sydney. At this location the Freeway embankment is about 30 metres high. The embankment was constructed about 25 years ago at a slope of 1.5 (H) 1 (V). Materials consist of compacted clayey silty sands & ripped sandstone with the slope protected by a layer of sandstone rock armouring. Heavy rains in June 1989 caused part of the embankment to become unstable with the head of the slip failure encroaching on to the roadway shoulder.

DETAILS OF THE SOIL NAILING WORKS:

It was considered essential that the slip not be allowed to intrude into the southbound running lanes of the Freeway. Two options were considered to maintain stabilty of the embankment at the roadway:

a) Micropiling Cost estimate @ $1 million
b) Soil Nailing Cost estimate @ $0.7 million.

In view of the cost savings the soil nailing option was adopted. Construction commenced during June 1990 and finished in early December 1990.

For the stabilisation 450 soil nails were installed in four benches with installation in two rows per bench. Bench heights are two metres and spacing of the soil nails is staggered at three metre centres. The soil nails were manufactured from Y20 deformed bar with centralisers, threaded at one end to take a facer plate and nut. Soil nails were 12 metres long and hot dipped galvanised for corrosion protection.

SEQUENCE OF THE WORK:

For the top two benches the nails were installed prior to the first layer of shotcrete, each bench being excavated in one metre height increments.

The compacted sandstone fill maintained a vertical cut face without collapse. Holes 75 mm diam. were then drilled using an air track working along the excavated bench and soil nails grouted in with a sand cement mix (20 Mpa) using a grout tube extending to the length of the hole.

Grout pressures were around 700 Kpa. After a section of the bench was soil nailed reinforcing mesh was placed on the excavated face and shotcrete applied. Subsequently the face plate/nut arrangement was installed with tensioning nominally to 10KN by hand wrench. A second layer of reinforced mesh shotcrete was then applied. Weepholes at regular spacings through the shotcrete were provided for drainage.

For the third & fourth bench a layer of reinforced shotcrete was applied first before soil nailing.

Throughout the remedial works traffic continued to run along the roadway. A jersey kerb was used to close the slow lane for construction access. The clearance between the excavated edge and the running lane was around five metres. Traffic vibrations did not affect the work.

The soil nailing work was completed in early December last year. The second part of slope restoration works involves construction of a gabion wall at the toe area of the slide. The embankment will then be regraded to 24 degrees up to the base of the soil nailing work.

MONITORING:

In view of the importance of the work and the maintainence of traffic safety a comprehensive monitoring programme was set up involving:

a) Vertical inclinometers to measure any lateral movement in the embankment.

b) Measurement of strains developed in six fully instrumented soil nails with continuous data logging systems.

c) Regular monitoring of water levels in the embankment.

d) Proof load tests on selected soil nails to check grout adhesion.

e) Long term corrosion monitoring of selected soil nails.

PERFORMANCE OF SOIL NAILING WORK:

No measurable movement has occurred in the soil nailed embankment to date. Data logging of strains in the soil nails indicate that there is some tension developed in first 3 to 5 metres of the bench face but these are well within the capacity of the bar which is 150 KN ultimate load.

2. ROCK RIPPABILITY STUDY

AIMS:

To determine the factors which influence the ability of a bulldozer to rip rock.

To develop a model(s) of the ripping process.

To improve the methods for predicting rippability.

AREAS OF RESEARCH:

i) Review of existing literature.

ii) Collection of geological, seismic and ripping data from construction sites.

iii) Numerical modelling of the ripping process.

iv) Laboratory scale modelling of the ripper penetration into artificial rock.

v) Instrumentation of a bulldozer to determine forces in the ripper tyne.

vi) Analysis of data.

PROGRESS:

i) Review of existing literature has been completed and a copy circulated to all Regions (September 1990).

ii) Collection of field data includes:

- <u>Geological Data</u> (rock type, strength, weathering, fabric, structure, jointing pattern, direction and spacing of joints, continuity of joints, seismic velocity).
- <u>Ripping Data</u> (bulldozer size, type and condition of ripper boot, description of ripping area, direction of ripping, ease of ripping, mechanisms of rock breaking, depth of tyne penetration, length of ripping runs, penetration angle of boot.

* <u>Laboratory Tests</u> (tests conducted on rock samples from ripping areas include point load tests, unconfined compressive strength tests including Young's modulus and Poisson's ratio, Brazilian (indirect tensile) tests, modulus of rupture (flexural) tests, triaxial tests, sonic velocity tests, porosity, density and moisture content.

iii) Preliminary numerical modelling using two dimensional analyses have been carried out but it has become obvious that significant three dimensional effects are involved. There are currently two types of models available for 3D analysis - finite elements and discrete element analysis. Discrete elements are better able to model the movement of blocks of rock along defined joint planes however they do not allow for the rock to break anywhere than along the predefined joints. A suitable 3D analysis program has yet to be implemented.

iv) Laboratory scale modelling is being used since to test the effect of different variables on ripping it is necessary to have a controlled testing environment. During testing of an artificial "Hawkesbury Sandstone", using an instrumented scale model tyne, forces on the tyne are measured using strain gauges. These forces will be compared to those measured on a full size dozer during the instrumented field trials and can be used to check the suitability of the numerical model.

v) Preliminary analysis of data has clearly demonstrated the unreliability of <u>all</u> existing methods of rippability prediction.

3. SATELLITE IMAGERY BASED REMOTE SENSING IN R.T.A.

(ESIPP - EARTH SCIENCES INFORMATION PROCESSING PACKAGE).

Remote sensing imagery using TM images produced by ESIPP has been successful in detecting and mapping in great detail soils and rocks at Fowlers Gap in semi arid far western NSW. The cropping of soils and other agricultural practices further east gives images that require more expert interpretation but compared to older techniques this imagery is a vast improvement in both accuracy and time for mapping and detecting soils and rocks.

All that is required is a PC (NEC 386 or equivalent) and a suitably qualified person (eg Scientific Officer) to work the ESIPP package.

There are optional extra components such as maths coprocessor and screen that give better imagery but an outlay of $5000.00 will cover supply of the software package plus these extras for use with an existing NEC 386.

Planning and design of new and maintenance of existing road routes requires input of as much data as can be reasonably obtained on soils, geology (rock types), native animal habitats, archaeology and vegetation groups (particularly rare and unusual plants) as a preliminary to more expensive EIS and REF preparation and planning and to discover if there are certain areas that are best excluded for route consideration at a early stage. Remote Sensing using ESIPP enables rapid mapping of present native and cultivated vegetation and can be used as a valuable aid in interpreting desirable and undesirable geology and soils (subgrades). It can also be used to indicate potential archaeological problem areas.

Practical Benefits Compared to Air Photos:

* Large area of coverage. (eg 40 km by 40 km)
* area coverage can be obtained at regular intervals for comparison purposes.
* variable scale to suit the needs.
* any section of the image can be produced at various scales at any time after the imagery has arrived.

* all images are seen from near vertical allowing direct comparison to existing maps.

* covers several bands of the visible and infra red (beyond human sight) greatly increasing capability to discriminate features.

Cheapness for Area Covered:

An ESIPP image is an up to date "picture" (within a few weeks of the satelite pass if required) of a relatively large section of the landscape with cost benefit per area covered. Images can be produced at various scales (covering several hundred square Km) at a fraction of the cost of air photos (although the images are not as clear as photos).

FUTURE DEVELOPMENTS:

Radar Imagery:

Over the next few years a new form of radar imagery will be flown similar to air photos using conventional aircraft and from earth orbiting satellites.

This radar will give an "X ray" type view of the earths surface being able to penetrate the top metre or so of the soil surface to reveal the underlying deposits of importance to road building and maintenance such as sands, gravels or shallow bedrock. This imagery will be produced in a similar way to Landsat imagery as a picture like image and can be easily viewed and enhanced using ESIPP.

The UNSW is planning a project with NASA using this radar over a portion of Australia.

4. COMPUTER PROGRAMS OBTAINED UNDER THE R & D PROGRAM AND TRIALLED FOR USE IN THE GEOTECHNICAL AREA.

These programmes will be discussed under five headings:

1. FLAC AND AFENA
2. U D E C
3. BESOL
4. PC SLOPE
5. OTHER PROGRAMS.

i) FLAC AND AFENA

PROGRAM DESCRIPTION:

These Finite Element programs are able to model the behaviour of structures built on rock and soil. They can handle elastic and nonlinear material behaviour and the reinforcing effect of structural elements such as ground anchors can be analysed.

APPLICATION:

Prediction of movements/stresses around excavations such as road cuttings, tunneling, slope stability, effect of soil reinforcement methods e.g. soil nailing, effects of mining subsidence, ground water flow and pavement analysis.

This leads to design of safe road cuttings and slopes where road design geometry can be optimised.

ii) UDEC

PROGRAM DESCRIPTION:

A 2 dimensional numerical modelling code simulating the behaviour of rocks where jointing and block movements control the deformation. The following features of fractured rock masses can be simulated:

a) variable rock deformability
b) complex joint structures
c) non linear, inelastic joint behaviour
d) seepage

APPLICATION:

Assessing the stability of jointed rock masses in road cuttings leading to safe designs, optimisation of batters for road design, effects of mining subsidence on roads and bridges.

The effects of rockfall and methods to restrain rockfalls onto roadways can be analysed to protect the public.

iii) BESOL

PROGRAM DESCRIPTION AND APPLICATION:

A 2 dimensional boundary element program to analyse for the effects of excavations e.g. road cutting stability and mining subsidence problems. The method can take account of strength differences in layered rock strata.

iv) PCSLOPE

PROGRAM DESCRIPTION:

Program gives Factor of Safety calculation for soil slope stabillity by limit equilibrium methods. Both circular and non circular (sliding type) failures can be analysed. Complex subsurface soil profiles can be handled.

PROGRAM APPLICATION:

Landslide repair works, design of road cuttings and embankments, effect of loadings on slopes, e.g. railway line adjacent to the crest of a steep slope.

v) OTHER PROGRAMS

The Geotechnical group has available other programs for the following:

* Retaining wall analysis e.g. crib and gabion walls
* Settlement predictions e.g. roads over swamps
* Pile design e.g. for bridges.

5. IMPROVED GROUND ANCHOR SPECIFICATION

The improved ground anchor specification has drawn heavily on two documents:

* British Standard Code of Practice for Ground Anchorages - BS 8081 : 1989, and

* Hong Kong, Civil Engineering Services Department, Model Specification for Prestressed Ground Anchors - Geospec 1 1989.

Major changes to the Authorities old specification have been made in the areas of:

* materials
* testing procedures
* installation procedures
* monitoring provisions.

Materials

Under this heading requirements have been added for grout consistence (viscosity), limitations have been placed on certain cation concentrations in the grout and limits on water cement ratio have been stated.

To ensure corrosion protection (and not attack) of the cables is achieved grease properties are specified for the first time.

Sheathing properties have been tightened (minimum thickness specified, spiral shape specified to ensure better bonding, impermeable sheath specified).

There are no changes to strand requirements.

Testing Procedures

There are major differences between the new and old specification with respect to anchor testing.

The old specification allowed for determination of load by measurement of cable extension which is not applicable to ground anchors since, by the nature of their installation, cables can be "caught up" with resultant dissipation of forces.

In the old specification a single test consisting of five (5) load increments and five (5) unloads was allowed whereas the new specification requires comprehensive testing on a few select anchors. This allows for more correct interpretation of anchor performance.

Installation Procedures

The new specification tightens the requirements for water testing of the hole, provides tolerances on hole alignment and deviation and covers the possibility of hole casing being required.

The new specification only allows one stage grouting compared with two stages in the old specification. This had given problems with laitance forming at the interface of the two grout stages. In the new specification the free length is completely enclosed in grease and sheathing.

Monitoring Provisions

There were no monitoring provisions in the old specification whereas the new one provides for 10% of anchors to be monitored at specified intervals.

NSW HEAVY VEHICLE CRASH STUDY

Presentation by

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1. INTRODUCTION

Heavy vehicle safety became an important issue in the late 1980s. Changes in the heavy vehicle speed limit, media treatment and several serious crashes involving heavy vehicles combined to raise community awareness. There was also increasing evidence that the road transport industry was operating under high pressure, leading to reported abuses of such regulations as speed limits and driving hours.

During late 1988 and early 1989, the Road Safety Bureau of the Roads and Traffic Authority became aware of a growing problem with fatal heavy vehicle crashes in NSW. Fatal crashes involving articulated trucks increased from 59 in 1987 to 120 in 1988. This represented an increase from 30% of Australia-wide fatals to 48%. By comparison NSW represents 31% of Australia's vehicle ownership, 34% of Australia's truck km of travel and 35% of the road freight task (tonne km) (SMVU data).

Fig 1.1 shows the trend of articulated truck fatal crashes over the period 1981-89 and allows comparison of Australia-wide and NSW data. It is apparent that the NSW reducing trend over the period 1984-87 is the most outstanding feature, and this was clearly reversed in 1988. The doubling of fatal crashes in NSW, and a corresponding 25% increase nationally, prompted the Road Safety Bureau and the Federal Office of Road Safety to jointly launch a detailed analysis of fatal and serious injury crashes involving heavy vehicles.

A consortium of consultants from Road User Research Pty Ltd, the Monash University Accident Research Centre, Monash University Department of Civil Engineering and R.A. Pearson and Associates was commissioned on September 27 1989 to undertake a detailed study of heavy vehicle crashes in NSW . The brief is reproduced in Appendix A.

The study aimed to (i) ascertain the circumstances of, and factors contributing to, fatal and serious injury crashes involving heavy vehicles and occurring in 1988 and 1989 and (ii) provide a basis for developing countermeasures to improve heavy vehicle safety.

The study consisted of three strands:

(i) Detailed examination of all available data on fatal and serious injury crashes involving heavy rigid trucks, articulated trucks and long distance coaches in NSW, concentrating on the Hume and Pacific Highways, and covering 1988 and 1989

(ii) Detailed analysis of the NSW mass crash data, covering 1982 through 1988, and determining how 1988 heavy vehicle crashes may have differed from previous years

(iii) Detailed analysis of exposure and economic data, covering travel, tonne-km and weather data for the period 1982 through 1988.

This multi-level approach was structured to gain a specific understanding of the NSW truck crash problem and to provide the basis for the development of countermeasures which could be implemented via NSW Government policy or Federal Government policy.

A number of specific research questions were formulated by RSB:

(i) Given that NSW in 1988 had a large problem with fatal articulated truck crashes, was the problem significantly different from other years?

(ii) Why are the Pacific and Hume Highways apparently a problem?

(iii) Given that fatal articulated truck crashes were higher in 1988 than 1987, why was the total number of articulated truck crashes lower in 1988 than 1987?

(iv) How does the heavy vehicle crash situation in 1989 compare to previous years?

(v) What were the causes and circumstances of heavy vehicle fatal crashes occurring in 1988 and 1989?

(vi) Were heavy vehicles more involved as cause or "key vehicle" in crashes in 1988 than in 1987 or 1989?

(vii) Did economic and travel activity in 1988 differ from that in 1987? If so, how?

(viii) What specific countermeasures are indicated by the outcomes of the study?

Question (i) is addressed in Strand 2 (Section 3) and in Strand 1 (Section 2).

Question (ii) is addressed in all Strands.

Question (iii) is addressed in Strand 2 (Section 3) and in Strand 1 (Section 2).

Question (iv) is addressed in Strand 2 (Section 3).

Question (v) is addressed in Strand 1 (Section 2).

Question (vi) is addressed in Strand 2 (Section 3) and in Strand 1 (Section 2).

Question (vii) is addressed in Strand 3 (Section 4).

Question (viii) is addressed in Strand 1 (Section 2).

In addition, Strand 3 considered economic and travel activity 1982-87 and weather 1982-88.

Consolidated answers to the research questions are given in Section 5.1.

Although tightly structured by the RSB brief, the study did change emphasis as it developed. Visits to crash sites and discussion with local personnel proved a very valuable data source. It was found that serious injury crash data commensurate with data on fatal and serious injury crashes could not be obtained, so it was decided to proceed with the greater detail of fatal crashes rather than accept the lowest common denominator of the serious injury crash data. Therefore Strand 1 only covered fatal, and not serious injury, crashes. The determination of specific countermeasures proved to require interactive analysis and considerable attention was devoted to this aspect of the study.

This report documents the investigations carried out under the three strands (Sections 2, 3 and 4), presents the countermeasure investigation (Section 5), and presents the consolidated study findings (Section 6) and conclusions (Section 7). Supporting material is included in Appendices.

Source: FORS road crash statistics

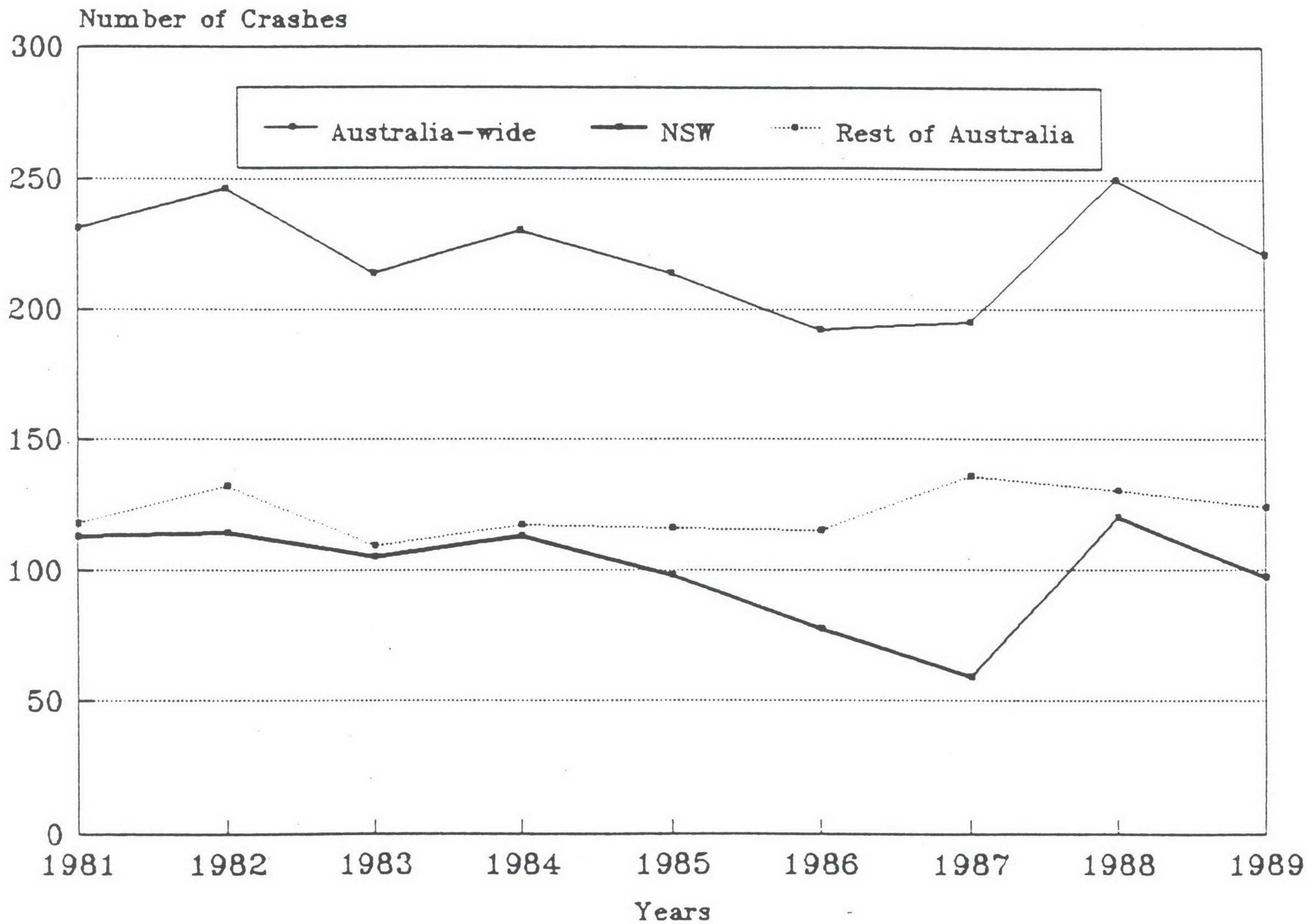

Fig 1.1 Articulated Veh. Fatal Crashes

FINDINGS AND CONCLUSIONS

(i) NSW Highways provide a significant part of the nation's interstate road freight routes. The Hume and Pacific Highways are estimated to perform 50% and 18% respectively of the nation's total interstate road freight task.

(ii) Traffic flow on the Hume Highway is some 60% higher than the Pacific and is believed to involve a higher percentage of trucks on the Hume Highway. Traffic flow is considerably more variable along the Hume than along the Pacific.

(iii) Both traffic and freight flows on NSW highways have grown significantly during the 'eighties, with freight flows showing considerable fluctuations superimposed on the upward trend.

(iv) The Hume and Pacific Highways are each the scene of 8-12% of the State's fatal truck crashes, and a somewhat lower percentage of the State's hospital admission truck crashes.

(v) The rate of fatal truck crashes per unit freight flow is approximately 3 times higher on the Pacific than the Hume. The crash rate on the Hume is reasonably typical of the crash rate on other N.S.W. highways.

(vi) Trends of fatal truck crash rates (either in terms of traffic flow or freight flow) tended to reduce during the 'eighties until 1988, when a significant increase occurred. These trends were similar on all NSW highways, but different from the Australia-wide situation which was more constant.

(vii) The number of NSW fatal truck crash is occuring in 1988 was above the predicted value based on the 1982-1987 downward trend.

(viii) In 1988, the major increase in truck crash types occurred in high speed zones, on undivided roads (involving head-on crashes with cars), involved unprotected road-users, or involved ran-off-road crashes on curves. These problems were acute on the Pacific Highway because

(a) it is a predominantly undivided road of poor standard (including narrow shoulders, presence of roadside objects, and a high incidence of poor horizontal and vertical road alignment),
(b) there is a high incidence of night-time crashes, often in wet conditions,
(c) car drivers on the wrong side of the road crash head-on into trucks (presumably due to inattention, fatigue and poor visibility) and
(d) trucks throughout NSW tend to travel at relatively high speeds (i.e. a significant proportion in excess of 120km/h).

(ix) Trucks were found to be responsible in about 45% of multi-vehicle fatal crashes involving trucks and in about 32% of truck-car crashes.

(x) In 1988, there was a large increase in interstate road freight flows originating or terminating in Sydney, and traffic flows increased significantly. However, conventional notions of the effect of these exposure indices on crash occurrence would not adequately explain the increase in fatal truck crashes throughout NSW in 1988. Other factors which were found to contribute to truck crashes in 1988, and which could potentially have changed from previous years, are: night-time travel (and poor lighting conditions), the behaviour patterns of road users in cars (involving inattention, fatigue and alcohol use), the behaviour of unprotected road users in a road freight environment (involving alcohol use and inattention), and the behaviour of truck drivers (involving excessive speeds and inattention).

(xi) Unless NSW adopts a long-range commitment to implementing a range of countermeasures to truck crashes, the NSW fatal truck crash problem is expected to be perceived to increase from time to time, and probably to show a general upward trend.

(xii) Major factors contributing to severe truck crashes in NSW were found to be: undivided roads, poor road alignment, light conditions (night-time), roadside objects, excess truck speed, poor road shoulders, slow car speed, truck instability,car driver alcohol use, truck driver alcohol use, car drivers falling asleep and excess car speed. Up to 60% of crashes could involve some element of driver fatigue, and up to 40% could involve excessive speed by truck or car drivers.

(xiii) Road alignment was found to be a particular problem on the Hume and Pacific Highways. Tight radius curves, especially in combination with abrupt grade changes, and compound or extended curves were found to threaten the controllability of both trucks and cars, contributing to severe crashes.

(xiv) Countermeasures having a high level of relevance plus specific mechanisms for reducing the fatal consequences of truck crashes were identified and relate to roads, vehicles, heavy vehicle drivers, car drivers and the road system environment. While the roads countermeasures should be particularly targeted at the high-risk Pacific Highway, all other categories of countermeasures can be expected to have significant benefits throughout NSW (and extending to other States).

(xv) While a large number of countermeasures deserve consideration for implementation, the most significant countermeasures are considered to be:

- Divided highways on major freight routes (this eliminates exposure to head-on crashes and poor road alignment).
- New technology in truck (structural) frontal redesign to deflect cars and absorb energy.
- Fitment of speed limiters in trucks to prevent excessive speeds (i.e. greater than 120km/h).
- Road improvements at known blackspots (including realignment).
- Use of the latest electronic technology for enforcement of alcohol limits (for both cars and truck drivers) and for enforcement of speed limits (for both trucks and cars).
- Improved road shoulders (with respect to width and condition).
- Police enforcement of speed limits and non-hazardous driver behaviour at known black spots.
- Improved road delineation with appropriate use and maintenance of refactorised devices, edge markers and adequate delineation during roadworks.
- Use of current and new technology to provide truck cab strength during rollover and frontal impact.
- Removal of impediments to truck drivers wearing of seat belts.
- New technology to alert sleepy truck and car drivers.
- New technology in car crashworthiness to maximize survival possibilities in offset frontal impacts with trucks.
- Reduction of truck aggressivity through removal of bullbars, lower front bumpers, energy absorbing bumpers and under-run protection.
- Elimination of insecure loading practices on trucks
- Marking and protection of culverts.
- Programs to educate other road users with respect to appropriate driving behaviour in a road freight environment, including speed and distance perception.
- Adoption by road freight operators of appropriate tools to eliminate hazardous truck operational practices and the introduction of an operator licensing and demerit system to enforce the use of such management tools.
- Heavy vehicle driver defensive driving training.

(xvi) The provision of divided highways is an outstanding countermeasure to the heavy vehicle crash problem. Plans to reconstruct the Pacific and Hume Highways need to be accelerated. Priorities for reconstruction should take into account the current incidence of poor alignment (involving tight radius curves combined with abrupt grade changes, and compound and extended curves), traffic volumes and the percentages of trucks in the traffic stream, particularly at night.

(xvii) It is important that truck crash issues continue to be monitored, evaluated and researched. It is recommended new initiatives relating to crash analysis and data sources, are taken into account in evaluating the effectiveness of countermeasures and finding new countermeasures.

OUTLOOK

While the study did not provide any predictive capability, some insights may be offered into the outlook for truck fatal crashes in NSW.

The crash numbers on specific highways can be expected to fluctuate considerably from year to year and trends, by definition, can only be identified with considerable hindsight.

However, there is some evidence that very significant truck safety problems will persist, and perhaps intensify. The Pacific Highway is experiencing an unacceptably high truck crash rate and major steps are now in hand to render the highway an effective road freight environment. Traffic and freight flows on the Pacific are still quite low, but can be expected to increase with intensified economic development in Southern Queensland.

On all NSW highways, the realities of long-distance travel for all types of road users will continue, and this will perpetuate the syndrome of the hours-of-darkness crash problem. There is evidence that, despite the downward trend of crashes in the mid-'eighties, road projects have not kept pace with the increased demands of traffic (both recreational and commercial), freight (both in terms of volume and just-in-time distortion), faster vehicles with drivers more isolated from the road environment, and inexperienced, overworked truck drivers.

There are already some other positive elements at work, including the speed limiting of trucks and moves for more realistic enforcement pratices. However, unless there is a long term commitment to implementing a much wider range of countermeasures the NSW heavy vehicle crash problem may deteriorate.

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Asset
Control
Technology

R T A

AN INTRODUCTION TO THE BRIDGE MANAGEMENT SYSTEM BEING DEVELOPED AND IMPLEMENTED WITHIN THE ROADS AND TRAFFIC AUTHORITY, NEW SOUTH WALES

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BRIDGE MANAGEMENT SYSTEM REQUIREMENTS

A needs assessment for a Bridge Management System within the RTA has determined that a comprehensive BMS needs to contain/provide the following modules/functions:

STRUCTURAL CONDITION RATING METHODOLOGY

An objective method by which the asset is inspected and its condition assessed. (It is necessary to know both the current network condition as well as its trends.)

DATABASE

A collection of all data relevant to the asset. This database would cover items such as:

(i) **Inventory** - generally the physical characteristics of the asset, eg, items such as length, width, maintaining Authority, superstructure type.

(ii) **Condition** - the condition of the elements that make up the asset, eg, condition of girders, piers, bearings.

(iii) **Upkeep expenditure** - details are required by location (ie, specific bridge) and activity (eg, concrete repairs).

EFFECTIVE DATA HANDLING

A means to query and display information from the database. In particular, the asset manager must be able to quickly identify those assets which are in poor condition and to statistically compare any changes in condition from one year to the next.

PLANNING AND CONTROLLING OF ANNUAL WORKS PROGRAMMES

Preparation of a needs based budget, as well as works scheduling, and the tracking of work output.

PREDICTION OF MAINTENANCE EXPENDITURE AND THE EFFECT OF DIFFERENT FUNDING SCENARIOS ON ASSET CONDITION

The maintenance budget calculated for the coming years should be the optimum budget that is required to satisfy management defined performance objectives (ie, asset condition standards).

EARLY PILOTS AND DIRECTION

These requirements were subsequently used for the assessment of two BMS's being piloted by the Authority. At the same time, the functionality of the Authority's existing PMS was being investigated for its possible adaptation to bridges.

As a result of these investigations and the failure of the trialled BMS's to meet a majority of the abovementioned requirements, it became more practical for the Authority to concentrate on adapting its own PMS methodology to bridges rather than to continue the trialling/adapting of externally available systems.

PROPOSED BMS

A comprehensive BMS, with the abovementioned elements/features, is now being developed/implemented within this Authority.

The modular structure of this proposed BMS is shown in Figure 1 below.

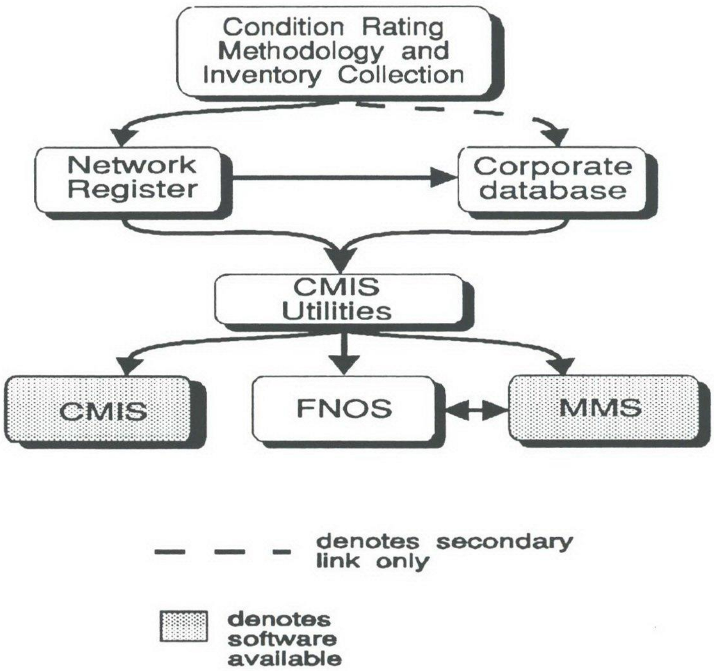

Fig 1 - Proposed BMS Modules

All modules, except for the Corporate Database, are PC based and perform the following functions. A more detailed description of each module is provided in the following Section.

Module	Function
Network Register	A PC database which stores bridge condition and inventory data
Corporate Database	RTA's mainframe database containing all bridge, road and traffic data
CMIS (Condition Management Information System)	Provides information about the condition/inventory of each bridge
CMIS Utilities	A system that converts condition rating data into a file format that can be read by CMIS, FNOS and MMS
MMS (Maintenance Management System)	A Project Management tool for bridge maintenance activities
FNOS (Financial Network (Optimising System)	A predictive budgeting tool that enables Asset Managers to predict (for a specified number of years into the future) the upkeep budget required to satisfy management defined performance objectives (ie, condition standards)

BMS MODULES

CMIS

The Condition Management Information System (CMIS) was released in February 1991. A much enhanced version is due for release in December 1991.

CMIS is a desk top information system that allows Bridge Managers to quickly and easily access their bridge network data. This data could be related to "condition" or "inventory" (including stored images) or a combination of both.

CMIS can be used as a stand alone module in organisations where the functionality of a FNOS or MMS is not required, eg, where the bridge network is small.

CMIS allows Managers to:

- Work with bridge data from their own (user defined) data base (December 1991 version).
- Store and view bridge photographs - (VGA monitors only) (February 1991).
- Produce graphical statistical analysis of different areas of the network (February 1991).
- Compare historical information (December 1991).
- Produce reports on condition characteristics (December 1991).
- Identify problem areas by displaying their location on a network map (December 1991).
- Calculate routine maintenance costs (December 1991).

With CMIS, Managers can quickly answer questions such as,

- How many timber bridges are there on a particular route or within a particular (Local Government) Area?

  CMIS allows you to look at them in detail on screen or in a printed report.

- What is the age distribution of the network?

  CMIS allows you to produce a graph of the age distribution on your screen or as a printed report.

MMS

The Maintenance Management System (MMS) was released in September 1991. An enhanced version will be released late 1992.

MMS is essentially a Project Management tool that provides bridge managers with a tool for the planning, organising, directing and controlling of bridge maintenance activities.

An important aspect of MMS is how it uses the knowledge of local work crews to develop procedures and outputs for a range of maintenance activities.

With MMS, bridge managers are able to

* log maintenance work identified on inspection reports
* develop an annual work program
* distribute the planned work load throughout the year
* collect and process data about work accomplishments (output) and costs
* produce evaluation reports comparing work planned to work accomplished
* track expenditure details for individual bridges

FNOS

The Financial Network Optimisation System (FNOS) for bridges is under development. A pilot version, to test possible bridge deterioration models, will be completed by December 1991. The deterioration models to be used are based on the Markovian principle.

FNOS enables bridge managers to predict (for a specified number of years into the future) the budgets required to satisfy management defined performance objectives (ie, bridge condition). FNOS achieves this by using, amongst other things, accurate historical costing of the maintenance work performed on different types of structures. This information is held by the MMS module. As such, use of the FNOS module would also require the use of the MMS.

With FNOS bridge managers are able to:

* assess effects of different funding scenarios on network condition
* assess effect of different performance objectives on required budget
* predict the optimum (ie, minimum long term) budget required to satisfy the specified performance objectives.

NETWORK REGISTER AND CMIS UTILITIES

This software is at the concept stage only.

Network Register will be a PC database that enables entry and storage of bridge condition and inventory data. This data will then be transferred to the Corporate database or converted (via CMIS Utilities) into a file format that can be used by CMIS, MMS and FNOS. Data loggers and bar code readers may be used to input condition and inventory data to the Network Register.

Network Register will eventually become the preferred link for the transfer of field data to the Corporate database

CONDITION RATING METHODOLOGY

Under development (not software) - By Bridge Branch

While this Authority does have an existing methodology, the data is not collected/presented in a format that can be handled by computer. For this reason, inspection systems used by other Authorities, are being reviewed for their suitability to Bridge Managers as well as for other BMS software, particularly FNOS. These reviews will benefit from the release of the pilot FNOS for bridges software in December 1991.

NETWORK INVENTORY

Under development/enhancement - by Bridge Branch with ISB

As with Condition Rating, this Authority does have an existing database of Bridge Inventory (eg, items such as length, width, etc).

Data modelling sessions are being held to assess the demand for additional items to be entered/held by the enhanced system.

CONCLUSION

The development stage of each BMS module is summarised below:

CMIS (Bridges)	released February 1991 second release due December 1991
MMS (Bridges)	released in September 1991 second release due in August 1992
FNOS (Bridges)	pilot version available (for model testing) in December 1991
Network Register and CMIS Utilities	at concept stage only. Test version available December 1992.

Subject to the development/selection of a suitable condition rating methodology, by December 1992, the BMS will be complete.

Bridge Managers will then have the "tools" to readily assess:

- current network condition and trends
- maintenance expenditures (by bridge location and activity)
- effects of different funding scenarios on network condition
- the optimum maintenance budget required to satisfy management defined (structural) condition standards.

New Technology for Effective Pothole Patching

by
Peter Morris
Project Manager
Port Macquarie

ISSN 0816-9130

RTA
ROADS AND TRAFFIC AUTHORITY
CONTACT

TECHNICAL NOTES

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57.5 Fast Pavement Patching

The RTA has been trailing automated pavement patching equipment. These machines use air to blow out debris or water from pot holes or areas of damaged pavement, then spray emulsion to coat the repair, and finally add aggregate with the emulsion so that the mix is applied at high velocity and does not require compaction.

The three types of equipment used are the AMZ Patchmaster, the Asphalite Patch Mobile and the Jetpatcher.

Favourable comments have been made about the equipment:

- Patchmobile, which is a truck mounted unit, produces a cold mix. This machine is manufactured in Brookvale, NSW under license to Asphalite in USA. Asphalite claim it can place up to 10m^3 of material per day.

  Moree, Ballina and Glen Innes Works Offices have used the Patchmobile and the machine has been found good for crack sealing. The machine is quite fast, allowing enormous productivity increases.
- Jetpatcher is also a truck mounted unit producing a cold mix. This machine is manufactured in Queensland. It has been used by Casino and Lismore Councils, on North Stradbroke Island, and in New Zealand. The Councils found it useful for repairing pot holes during rain, for crack sealing, and it is claimed to be good for their patches/repairs. The hopper has a capacity of 2m^3 so with 3 fills can place up to 6m^3 of material per day.
- Patchmaster, which is a trailer mounted unit, produces a warm mix (Fig. 6). This machine is manufactured by AMZ in USA, and has been trialled by Orange and Port Macquarie RTA Works Offices. Port Macquarie carried out repairs of pot holes that were actually filled with water, and the repairs were still sound after some months. Traditional methods cannot do repairs in wet weather. Repairs are fast and cause minimal delays even in heavy traffic.

The RTA evaluated the performance of the above 3 machines, as well as an imported one from Rocco Asphalite in USA. All the machines performed well.

The major advantage of this type of machine is that there is no need for compaction of the applied mix as it is applied at high velocity.

The unit chosen for purchase by the RTA is a trailer mounted version of the Patchmobile. This unit will have an emulsion tank of at least 900ltr

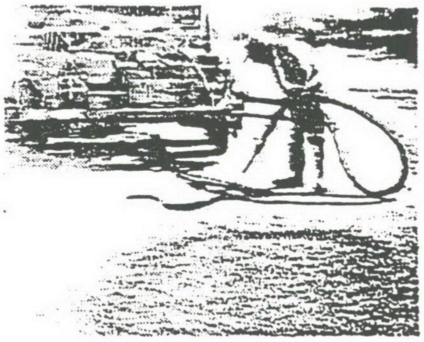

Fig. 6

capacity, and a compressor. The aggregate will be carried by the truck that tows this trailer mounted unit, and a hydraulic feeder connects to the patchmobile machine. The Patchmobile is being supplied by Seaboard Western Corporation Pty Ltd, Brookvale NSW.

The Patchmobile will initially be on hire to Port Macquarie Works Office. For further information contact Max Bonner, Fleet Management Section (02)897 3233.

A video has been compiled on the 3 machines trialled and is available from George Kriflik (02) 218 6942.

CONTACT is produced in the Research and Development Strategy Branch of the NSW Roads and Traffic Authority, Level 7, 260 Elizabeth Street, Surry Hills, NSW, 2010.

TRIAL OF AMZ PATCHMASTER - MARCH 1990.

Attached are photographs relating to one failure repaired during a trial of the AMZ Patchmaster. The significant points to note were that:

- The pavement was wet and the failure full of water;
- Light rain was falling;
- Traffic volume was medium to heavy;
- The repair took only ten minutes to complete.

Under these conditions repair of such failures utilising traditional methods is ineffective and of a temporary nature. The repair carried out using the Patchmaster functioned effectively throughout the wet period until permanent pavement repairs were completed in June 1990.

Pavement deterioration through the inability of traditional methods to repair failures such as this one during wet periods is a major contributing factor to the growth in pavement maintenance costs. Minor problems quickly grow into major failures needing large scale repairs at significant cost. The secondary cost involved in this is the cost to motorists through damage sustained in travelling over traditionally unrepairable pavements. Claims for such damage have grown substantially over the past three years of above average rainfall.

Benefits expected to accrue from the purchase of an AMZ Patchmaster are:

- Ability to complete immediate, effective repairs to road failures under all weather conditions;
- Reduction in the pavement maintenance cost due to the semi-permanency of the repair;
- Major productivity increases with the expected speed of completion of the repair;
- Reduction in damages claims for pothole related incidents.

At the cost of $100,000.00 per unit, it is anticipated that the capital cost will be recouped within two years.

P R Morris
Works Engineer

Encl

ROAD MAINTENANCE BY CONTRACT

Malcolm Frost
Road Asset & Council
Administration Manager
Sydney Western Region

ROAD MAINTENANCE BY CONTRACT

Introduction

On 1 July 1991 work commenced on the first Quality Assurance term road maintenance contract in the world, and the first term road maintenance contract in New South Wales. This took place on certain state roads in the Sydney Western Region.

This paper outlines the process leading up to 1 July and the contract now in place.

The paper is presented in two parts.

- Part 1, a summary of the conference presentation outlining the background, procedure and future of contract maintenance in a strategic asset management framework, and
- Part 2, an overview of the road maintenance contract implemented in the Sydney Western Region.

PART 1 - PRESENTATION SYNOPSIS

In the time available for formal presentation it is not possible to address both the strategic and operation issues aspects of maintenance contracting. I have chosen the strategic aspect as the subject of the presentation.

This part is divided into the following topics:

- Asset management in Sydney Western Region
- The Booz Allen Hamilton review
- Contract development
- Performance evaluation
- Potential
- Future directions

1.1 Asset Management in Sydney Western Region

* The structure of the Sydney Western Region, now reflected in the corporate structure, focuses individual management units on key result areas.

* Central to the structure is the separation of the strategic planning functions from the operational functions. The regional units maintain full accountability for all planning, programming, policy and strategy. The operational units are accountable for programme delivery on time, to cost and quality.

* One of the key elements of the regional structure is the recognition of asset management as a high-profile entity. This was the first formal recognition in the Authority that asset management is more than road maintenance.

* Asset management comprises many elements, the most significant being maintenance. Also included are asset design, asset usage, material standards, record management, life cycle economics and heavy vehicle enforcement.

* By separating strategic from operational aspects of maintenance the ability was created to more critically examine work practice and policy.

* In the current economic and management environment it is critical that maximum value be derived from every maintenance dollar expended. Pavement and maintenance management systems should provide some improvement in day labour performance, but do not necessarily minimise our maintenance costs.

1.2 The Booz Allen Hamilton Review

* A major impact of the 1989 Booz Allen Hamilton review was the raising in emphasis of maintenance, and its management.

* The maintenance section of the review concentrated on Pavement Management Systems, under development at the time, Maintenance Management Systems, planned for future development, and Contract Maintenance, under consideration in Sydney Western Region at the time.

* The Booz Allen Hamilton team recommended that the MMS and contract maintenance pilots be undertaken by the Sydney Western Region due to the prominence placed on asset management in the regional structure.

1.3 Contract Development

* I could see no value in attempting to develop a contract from first principles. With little or no maintenance contracting done in Australia it was decided to invite international Expressions of Interest, and proposals, for the development task.

* 53 expressions of interest were received from Australia, the United States and the United Kingdom. Proposals were invited from 46, and interviews conducted with the majority. 20 proposals were received, incorporating a number of joint ventures between the original interested consultants.

* Assessment was undertaken by a panel of engineers from regional operations, Strategy Directorate and Vicroads. The assessment criteria were experience, methodology, understanding of needs and cost. The panel recommended that further negotiations proceed with two consultants.

  Frank Graham International (UK)
  Crooks Michell Peacock and Stewart in association with Sweroad, Scott Wilson Kirkpatrick (UK) and George Corderoy (UK)

* Interviews and final assessment were undertaken by myself and Garrie Vidler in London. Crooks Michell Peacock and Stewart were selected, as their team provided the best balance between proven experience and knowledge of Australian conditions and contract procedures.

* The United Kingdom contract system has private sector project managers acting as superintendent of the major maintenance contracts. These project managers are paid on a percentage fee basis, equivalent to the fee basis existing between the UK Department of Transport and Local Government agencies.

* The use of project managers allows for the separation of the planning functions and operational functions. The project managers deliver programmes determined by the Department of Transport, free from outside influence. Similarities between this approach and the Sydney Western Region structure were readily apparent.

* It was considered that optimum performance for the pilot project could be obtained in Australia by adopting similar practice.

* The contract that is now in progress is the first Quality Assurance term road maintenance contract in the world. The documentation is an adaptation of UK documents, the Authority's model QA road construction specifications and NPWC3.

* The documentation for the project management contract involved the development of new General Conditions and of a "Code of Practice" type specification.

1.4 Performance Evaluation

* As the project is a pilot of the technique in Australia it is essential that its performance be properly evaluated. Interest in the evaluation has been expressed by senior management of the Authority, the Labor Council, contracting associations and other State Road Authorities.

* An evaluation plan has been prepared in consultation with the Authority's Performance Evaluation Branch and the Labor Council. The plan focuses on appropriateness, efficiency, effectiveness and economy. Reports will be produced periodically. An initial report is due in December 1991.

* To facilitate the evaluation the project managers will manage the contractors on one network, and use identical procedures to manage the RTA on a similar network. Both "contracts" will be compared to traditional day labour performance.

1.5 Potential

* Overseas experience is that productivity has improved between 10 and 47 percent as a result of competitive tendering for road maintenance. Experience also shows that this saving has been maintained or further improved in subsequent contract terms.

* Other potential benefits are the increased flexibility resulting from "as and when required" type contracts. Planning and programming are not constrained by organisation effects.

* Apart from the potential for productivity improvements, the pilot will address other factors which may improve day labour productivity.

  - production of maintenance quality systems
  - specifications for maintenance activities
  - improved work practices
  - project management skills for maintenance managers
  - maintenance policy and guidelines
  - award conditions
  - complaint processing.

1.6 Future Directions

* It is too early to assess the performance of the pilot project, however, the tendered rates are most competitive. Should the pilot prove successful it does not necessarily follow that contract maintenance is the best approach for New South Wales, or Australia.

* It may be that the pilot will show that there is an optimum split of works between contract and day labour. This split might be based on geographic areas, activities, or types of road.

* Once committed to contract maintenance, wide scope is opened for new styles of contract, appropriate for different situations. Two such possibilities are the integration of state roads with regional and local roads, and performance style contracts.

* It is my view that the contract procedures now in place in Sydney Western Region will prove to be the appropriate approach, for urban areas, and be capable of being readily adapted for rural areas.

* I believe we must accept that it is a matter of "when" and not "if" we introduce large scale competitive maintenance contracting into the public sector, on the basis of operational cost savings delivering greater benefits to the NSW taxpayer, If this proves to be correct the future type and application of contracts is only restricted by our imagination.

PART 2 - THE ROAD MAINTENANCE CONTRACT

This part of the paper outlines the road maintenance contract project now implemented in the Sydney Western Region.

The part is divided into the following sections:

- Nature of the Contract
- General and Special Conditions
- Schedule of Rates
- Specification
- Ordering of Work
- Project Management Contract
- Code of Practice

2.1 Nature of the Contract

* A Term maintenance contract for a period of two years on a network of Freeways, State Highways and Main Roads.

* A Schedule of Rates type of contract, with no total tender price.

* Quality Assurance in accordance with AS2990, Category B.

* Includes all maintenance activities on the networks with the exception of traffic signals and bridge structure maintenance.

* Work only undertaken by the Contractor under instruction from Superintendent.

* Allows for undertaking works of a non maintenance nature.

* Allows for separate tenders to be called for items valued at greater than $250,000.

2.2 General and Special Conditions

* General Conditions of Contract is NPWC3 1981).

* Special Conditions of Contract were drafted specifically for the term maintenance contract and are a major variation to those used on construction contracts. Many of the clauses of the General Conditions are deleted, replaced, qualified or amended by the Special Conditions.

* A copy of the Table of Contents from the Special Conditions is attached as Attachment 1.

2.3 Schedule of Rates

* The Schedule of Rates contains over 1000 pay items, representing all works likely to be required in the term of the Contract.

* Provisional quantities have been provided for all pay items, on the clear understanding that there is no commitment for any work to be undertaken.

* The contract specifies various working hour restrictions, grouped and coded. The contract allows for the contractor to tender a percentage surcharge to be applied to any pay item ordered under a working hour restriction.

* Copies of Table of Contents, and an extract from the Schedule are attached as Attachments 2 and 3 respectively.

2.4 Specification

* The specifications are adapted, where possible, from the Quality Assurance Road Construction Model Specification.

* Where QA specifications were not available at the time of tender Quality Control model specifications were used. The Contractor has tentatively agreed to replace the QC specifications with QA specifications when they are available, without adjustment to tendered rates.

* The model specifications have been modified in accordance with directions for road construction contracts by strikethrough of deleted text and insertion of new text in a different type font. This gave the tenderers a clear indication of the differences between a road maintenance contract and a road construction contract.

* A new model road maintenance specification is being developed by formalising the amendments to the current specification.

* A copy of the Table of Contents for the Specification is attached as Attachment 4.

2.5 Ordering of Work

* The contractor only undertakes work under the contract when in receipt of a site instruction from the Superintendent, authorising the work.

* The site instruction provides the contractor with the following information:

- Location of the Work
- Description of the Work required
- Applicable pay items and quantities
- Amount payable for the Work
- Working hour restrictions
- Date/Time for completion (Response Time)

* Several pay items will be applicable to any site instruction, increasing the flexibility of the contract. For example, a site instruction for a pavement patch will contain pay items for establishment and removal of traffic control, maintenance of traffic control, sawcut, excavation, pavement patch, wearing surface, linemarking and possibly establishment of plant.

* The contractor is paid on the basis of progress on site instructions.

2.6 Project Management Contract

* With minor exceptions, the power and duty of the Superintendent of the Term Maintenance Contract has been delegated to Project Managers.

* A separate contract exists between the Authority and the Project Manager. It is essential for the Superintendent of the project management contract to also be Superintendent for the term maintenance contract.

* Establishment items in the project management contract are Lump Sum, the remainder being Schedule of Rates.

* The project manager effectively acts as an Authority works centre. The project manager is accountable for managing maintenance of the network within an assigned budget. Duties include:

- Inspections of the Network
- Programming and Ordering of Work
- Contract Supervision
- Reporting on Complaints and Accidents
- Emergency response
- Maintenance treatment design
- Certification of Progress Certificates
- Management Reporting and Financial Control
- Quality System management

* For specific or restoration projects the project manager and the Authority agree on programmes prior to ordering of work.

* The project manager holds $20M public liability insurance and $10M professional indemnity insurance.

* Quality assurance in accordance with AS2990 Category B.

* The Conditions of Contract were written specifically for this work. A copy of the Contents is attached as Attachment 5.

2.7 Code of Practice

* The Code of Practice is essentially the technical specification for network maintenance management by the project manager.

* The code is based on similar documents used in the United Kingdom and Europe, and was prepared initially as part of the maintenance contract documentation by a UK consultant to Crooks Michell Peacock and Stewart.

* The Code of Practice is a dynamic document, under constant improvement and revision. It establishes:

  - Inspection strategy
  - Maintenance objectives
  - Maintenance limits and policy
  - Intervention Standards
  - Defect Assessment

* A copy of the Table of Contents from the Code of Practice is attached as Attachment 6.

INSTRUMENTATION FOR ROAD AND TRAFFIC DATA COLLECTION

F. G. Clerk
Manager, Engineering Services
Australian Road Research Board
October 1991

INSTRUMENTATION FOR ROAD AND TRAFFIC DATA COLLECTION

1. INTRODUCTION

Developments in instrumentation research for road and traffic data collection undertaken by the Australian Road Research Board are described for the broad areas of traffic counting and classifying, weigh in motion, and measurement of road characteristics.

2. TRAFFIC COUNTING AND CLASSIFYING

2.1 Roadway Sensors

Improvement in the performance of traffic detection sensors used for traffic surveys has been a key goal of recent research. Evaluation of a number of roadway sensors and fixing systems has been conducted, with a view to identifying methods for attaining optimum life and performance from existing detectors, and to trial and develop sensors based on newer technologies.

Test strips were installed on major roads and regularly monitored. The results and conclusions of this work have been incorporated into a new report entitled 'Vehicle Axle Detectors - Recommendations & Developments for Reliable Traffic Surveys' by Roland Leschinski.

2.2 VDAS Counter & Classifier

The Vehicle Data Acquisition System (VDAS) counts and classifies vehicles using either treadle, pneumatic or more recently, plastic film piezo detectors.

Ongoing improvements to the system include:

* a completely new enclosure, having improved resistance to water ingress and vandalism.
* the incorporation of a newly designed electronic sub-system to interface to piezo-electric detectors. The advantage of this system is that it can automatically compensate for changes in sensor output level over its lifetime, thus improving the long term reliability.

Current research is aimed at evaluating newer methods of detecting and counting vehicles. Ultrasonic, infra-red, microwave and other technologies will be evaluated.

2.3 Video Vehicle Detector

For more complex traffic data collection situations, ARRB has recently made available a much enhanced version of the video vehicle detector.

Unlike the VDAS counter, this system does not use any form of roadway detectors, but is able to extract information about traffic counts (and speed) either directly from a video camera placed above the roadway, or from a standard VHS videotaped recording taken from such a camera.

The key advantage of the system is that the analysis is very flexible. Once a video tape has been made, the tape can be simply loaded into the Video Vehicle Detector recorder and played. The intersection scene is initially frozen, and then by using a mouse, the user may place up to 32 imaginary detectors on the roadway scene at locations of his/her choosing. The tape is then played as normal, and the vehicles are counted and logged by the computer automatically.

3. WEIGH IN MOTION

3.1 Low Speed EMU

The low speed Electronic Mass Unit (EMU) for weighing axles was developed by ARRB some years ago. It uses an in-road plate system supported on load cells. Enforcement accuracy is obtained by rolling the vehicle to be weighed over the plate at 5 km/h or less, and then accumulating the individual axle loads, for a total vehicle weight.

The original system used a dedicated microprocessor and results were output on a small printer.

Recently, an upgrade for EMU has been developed, and the system is now known as PC EMU. The microprocessor/printer unit has been replaced, and the weigh plate electronics have been interfaced to an IBM compatible PC. This, coupled to a new moving character matrix display, makes EMU a much more usable and productive system. PC EMU can be supplied by ARRB as a complete system, or as an upgrade to the older type of EMU.

3.2 High Speed EMU

A high speed Electronic Mass Unit (HSEMU) has been commissioned recently by RTA at Mt. White. Trucks pass over the HSEMU plate at speed, and the vehicle weight and classification are assessed. The system controls a traffic signal, which directs non-conforming vehicles in for static weighing, or directs conforming vehicles back onto the expressway.

The station was opened during June this year. Some teething problems have been experienced with this first application of HSEMU, leading to the implementation of a revised method of restraining the load cells, and the development of an improved piezo-electric sensor interface. The site is currently operational with few problems remaining. Weight measurement has been shown to be significantly more accurate than expected.

3.3 Multi-lane CULWAY

A multi-lane version of CULWAY, the culvert based vehicle weighing system, has been designed, and a prototype system is currently undergoing field trials on the Princes Highway at Pakenham, Victoria. Multi-lane CULWAY can record data from up to 4 lanes simultaneously. It is based on completely different processors and operating system to the conventional single lane CULWAY. Special software has been developed to resolve vehicle weights in adjacent lanes.

A new plug compatible piezo interface is being developed for both CULWAY systems. It is expected that this interface will significantly improve the reliability of piezo sensor detections.

3.4 Fibre Optic Weighing

Work by Monash University on a fibre optic weigh in motion sensor is being supported by ARRB. Microbending of an optical fibre produces measurable changes in laser light transmitted through it. The sensor is still in the laboratory prototype stage, however it has the potential to provide static and dynamic detections, as well as weight information.

4. MEASUREMENT OF ROAD CHARACTERISTICS

4.1 Vehicle Mounted Roughness, Rutting and Profile Systems

Traditionally, road roughness has been the prime measure of pavement condition. The main instrumentation used for this measurement has been the NAASRA (AUSTROADS) meter, which essentially integrates the displacement between the differential and the body of a test vehicle, in counts per kilometre (1 count = 15.2 mm positive displacement).

It will be evident that such a measurement is dependent not only on the roughness of the road surface, but also the characteristics of the vehicle suspension. During the mid to late 1980's, ARRB developed a vehicle known as the laser profilometer. This employs 3 laser measurement units mounted on a beam bolted to the front of the vehicle.

The laser profilometer enables profile and rutting information to be gathered at highway speeds. Profile information is useful, in that it an be used to establish the International Roughness Index (IRI - defined by the World Bank, and not being dependent on suspension characteristics). A mathematical relationship was then established between the IRI (as measured by the laser profilometer), and Australian NAASRA roughness. This allowed the existing NAASRA meters to be calibrated using the profilometer, rather than requiring a standard NAASRA vehicle to be maintained for reference.

To facilitate the gathering of information on truck path rutting, a new 5 laser system has recently been prepared by ARRB for RTA.

Some re-working of the mechanical arrangement was found to be necessary during the commissioning phase, as the more complex beam and additional laser equipment were initially found to be difficult for the operators to remove and install (necessary during surveys). These difficulties have now been overcome.

4.2 The ARRB Walking Profilometer

Research effort is now being directed at the development of a 'walking speed' profilometer. A portable 'push along' instrument has been developed, which is undergoing trials.

The design is based on a novel hinged beam principle, mounted on four precision wheels. The two ends of the beam are free to move with respect with each other, such that the profile of the road surface can be described from analysis of the relative bend angles. A sophisticated transducer is used to accurately measure this bend angle. A sensor is fitted to one of the wheels to monitor distance travelled. A small personal computer is incorporated into the instrument, and this computes the required indices from the raw data. The profile is measured relative to a computed 2 metre straight edge, which is built up from the last eight 0.25 metre measured segments.

It is anticipated that this low cost device, which will calculate IRI, NAASRA roughness and some other indices, will find wide application for contract assessment, particularly for curing concrete pavements, bridge decks and short test sections.

4.3 Upgrade to Road Geometry Vehicle

An upgraded PC based logging system has been developed for the road geometry survey vehicle and this has recently been fitted to the vehicle owned by RTA. This system measures road geometry parameters such as grade, crossgrade and horizontal and vertical curvature at highway speed. The principal advantages of the upgrade include increased reliability over the earlier cassette recording system, greater storage capacity, improved user interface, and enhanced dead-reckoning accuracy.

4.4 Road Condition Measurement Technology

A new project which commenced in this financial year is entitled 'Road Condition Measurement Technology'. The scope of this work covers:

1. the investigation of technologies for measurement of road condition, including layer thickness and moisture movements, and

2. preliminary field trials of candidate technologies.

5. OTHER INSTRUMENTATION RESEARCH IN PROGRESS

5.1 Travel Time Logger

In addition to the work mentioned earlier, research is also underway on an improved in-vehicle logging system. As well as providing facilities for travel time data recording, the system has been designed for flexibility such that fuel consumption and other vehicle data may be readily recorded. This work is coupled to another project in which developments in Vehicle Roadside Communications are being monitored.

5.2 Timber Bridge Deflection

The conceptual design of a timber bridge deflection measurement system has recently been completed as part of a proposal put to RTA Bridge Section. There is a requirement for a rapid and reliable method of checking timber bridge deflection at several points, under a test load, as part of a periodic integrity check. An automated hydrostatic principle has been proposed in order to allow ultra low cost attachments to be left in place under the deck, such that periodic deflection checking can be done by one person.

6. CONCLUSION

Elements of current instrumentation research and contract work being conducted by ARRB have been described. ARRB is modernising its range of instrumentation and expanding its services to ensure it meets the needs of its members and other clients.

Sprayed Sealing Guide

by
Phil Walter
Manager Asphalt and
Sprayed Surfacings Unit
Material Services Section

Sprayed Sealing Guide

In 1988 a steering committee was commissioned to carry out an extensive review of bitumen sealing with the objective of improving the performance of sprayed seals. The results and findings from this work form the basis of the Sprayed Sealing Guide which has been written to assist personnel involved in maintenance, and in the selection and design of sprayed sealing treatments by providing a sound fundamental approach to good sealing practice and design.

The Guide stresses the need for attention to detail, good practice and constant monitoring of sprayed seals. The intention is to supply both experienced and inexperienced practitioners with a useful, working document.

The importance of regular follow up inspections of all sealing works is also stressed. This is essential to ensure that the work is performing according to the design requirements and conditions and that the intended effective life of the seal is achieved.

The information provided represents the most current state-of-the-art and has been drawn from the experience of our own staff, other State Road Authorities and overseas countries.

The Guide contains the Authority's revised sprayed sealing procedure which incorporates the recently updated AUSTROADS seal design method for seals and reseals, the VICROADS method for primes and primerseals, a revision of the Authority's design procedure for SAM and SAMI seals, a design procedure for geotextile reinforced seals, bitumen emulsion sealing and information on the use of related materials.

The Guide covers all of the administration, recording and monitoring procedures which will be necessary to verify the work at any point in time. The Guide may also be used in conjunction with both quality control and quality assurance specifications.

Due to the wide diversity of types of sealing work, it is essential that all practitioners use a common terminology in order to allow for meaningful discussion and comparison and sharing of experiences. This matter is addressed by the Guide in which an attempt has been made to standardize terminology in terms of work and material descriptions together with binder and aggregate application rates.

One important aspect of sealing work which is always present but is sometimes overlooked by practitioners is the environment and its effect on the selection, design and operational practice used for sealing. Mention is made of the environmental factors and their effect on sealing.

The Guide is structured to require an evaluation of the existing pavement surface to be made in the first instance. Where applicable the various pretreatment options, that can be carried out prior to a further assessment, are presented for consideration and implementation by the user prior to the selection of a sealing treatment. In the majority of cases, several sealing treatment options are possible but the final selection should be based on a life cycle costing.

The following general areas are covered in the Guide:

- administration
- terminology
- environmental factors
- assessment of the pavement
- available pretreatments and repairs
- selection of appropriate materials
- selection of a sprayed sealing treatment
- design of the sealing treatment

- application of the sealing treatment
- recording procedures
- monitoring
- remedial treatments

While the Guide covers sprayed sealing, mention of the use of asphalt and slurry sealing has been made for the sake of completeness.

The structure and interaction of the various sections in this Guide are shown in Figure 1.1.

An expert system, for use on a personal computer, has been developed for the seal design procedure described in this Guide and is available from the Materials Services Branch.

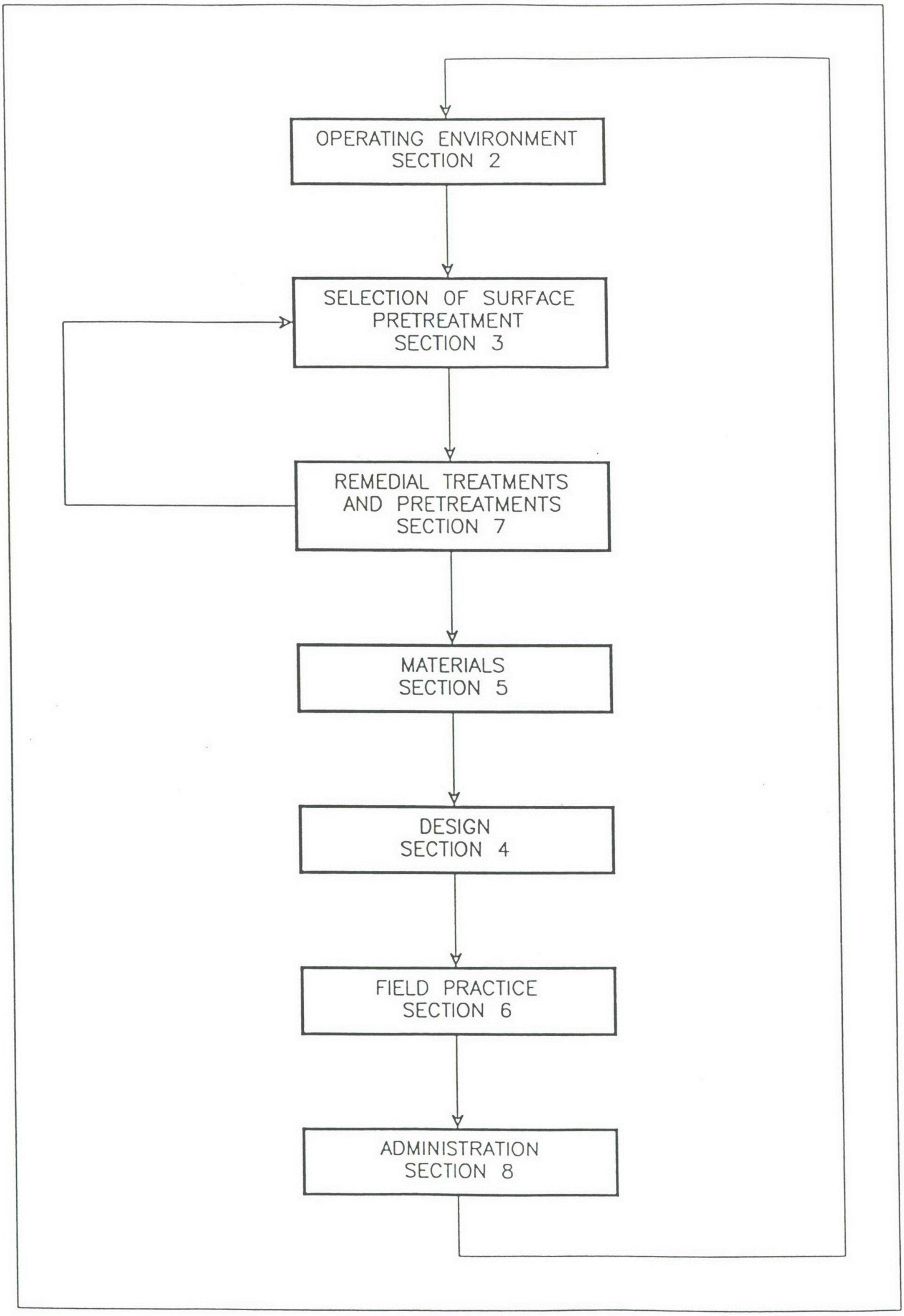

Figure 1.1 Interaction of Sections

TECHNOLOGY TRANSFER WORKSHOP

NEWCASTLE. 29 - 30 OCTOBER 1991

NOISE AND SKID RESISTANCE OF CONCRETE PAVEMENTS

GEOFF AYTON
RIGID PAVEMENTS AND CONCRETE UNIT
MATERIALS SERVICES SECTION

NOISE AND SKID RESISTANCE OF CONCRETE PAVEMENTS

The issue of traffic generated noise has become a topic of significant public interest in NSW over the past 3 years and consequently, pavement surfacings are being more critically assessed than ever before.

This issue creates a substantial challenge for highway designers in their search for a surfacing which is quiet and durable, with high friction characteristics. Unfortunately, there does not appear to be a single solution to the problem because the optimal surfacing will change according to factors such as:

* the predominant traffic speed
* the commercial vehicle content
* the continuity of traffic flow

There is little doubt that the quietest surfacing used in Australia is open grade asphalt (OGA) and for that reason it must surely rate as the most popular with the general public. Unfortunately, however, it will not be suitable for all situations (urban intersections being one example) and therefore other alternatives will provide the optimal solution in many cases.

In assessing the relative merits of the options, the following factors should be considered:

* friction
* noise generation
* ride quality
* spray generation
* maintenance demand
* life-cycle costs

A subjective ranking of the most common surfacings is given in Table 1. The ratings will obviously be influenced by the operating parameters (eg urban vs rural, traffic profiles and speed) and it is therefore intended purely to promote consideration of factors other than just noise generation.

Table 1: **Relative merits of surfacing options**

Surface type *	**Friction** (1)[2]	**Noise**** (2)[4]	**Ride quality***** (4)[3]	**Spray** (5)[5]	**Cost/ durability** (3)[1]
PCC-T	1	4	4	3	2
PCC-HD	3	2	3	5	1
OG-10	2	1	1	1	5
DGAC	5	3	2	4	3
SS-10	4	5	5	2	4

* **Key**

PCC-T: Portland cement concrete, tyned
PCC-HD: Portland cement concrete, hessian dragged
OG-10: Open grade asphalt, 10 mm
DGAC: Dense grade asphalt
SS-10: Sprayed seal, 10 mm

** "Noise" in this context refers only to the tyre-generated component.

*** "Ride quality" as used in this context is intended to denote "harshness" as perceived by the motorist, but independent of noise.

() Ranking of parameters for an urban freeway, speeds 80 km/h (+) within a noise-sensitive area (author's ranking).

[] Ranking of parameters for a typical 60 km/h urban arterial route (author's ranking).

Obviously, this exercise is a very subjective one, and residents in Wahroonga might challenge my ranking of the urban freeway parameters. Insurance companies would possibly be more amenable.

This is not the appropriate forum to discuss the relative merits of concrete and asphalt surfaces, and my motive here is purely to point out that there is no single solution to the surfacing problem.

By way of demonstration, I would point out that a greater part of our NSW network is surfaced with sprayed seals. They are both harsh and noisy, and in some areas exhibit questionable friction. However, to suggest that we should replace them with concrete or open grade asphalt would be unrealistic. (Indeed, the current debate regarding their relative merits would seem highly academic to the rural user at a time when many rural main roads are being returned to an unsealed condition.)

Notwithstanding, I think one comment is warranted here. I have heard suggestions, consequent to the public debate at Wahroonga, that we should cover many of our existing concrete pavements with asphalt. Anyone considering covering **hessian-drag concrete** with **dense grade asphaltic concrete** to reduce noise nuisance should examine the following figures and save the RTA a huge ongoing financial committment.

The following table is provided to put into perspective the typical noise, friction and roughness characteristics of concrete pavements relative to conventional alternatives.

Table 2: Comparison of surfacings for noise and friction

Generated noise levels for free-flowing*, constant speed motorway traffic are typically as follows, all values reported relative to conventional dense grade asphalt: (4)

Open grade asphalt (1987):	-6	dB(A)
Open grade asphalt (1975):	-4	"
Hessian dragged concrete:	-2.7	"
Dense grade asphalt:	0	"
Tyned concrete :	+0.3	"
Sprayed seal, 14mm	+2	"

Frictional characteristics of open grade asphalt and tyned concrete are similar at both 80 and 110 km/h.

Hessian dragged concrete is inferior to both of the above at high speeds, but is similar at speeds below about 80 km/hr. Dense grade asphalt, for all speeds, provides lower friction than each of the above three. The friction on sprayed seals is highly variable depending on aggregate characteristics and polishing rates.

NAASRA Roughness figures (counts/km) are typically within the range 30-60 on asphalt and 40-70 for concrete, each depending on the competence of the construction crews. Values of 25 - 30 can be achieved for both.

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* These figures are not relevant to situations where engine and braking noise may dominate the total noise spectrum. This is likely to be the case at speeds below about 70 km/h, in zones of acceleration or decceleration, and on grades exceeding about 5%.

RECENT DEVELOPMENTS IN CONCRETE SURFACINGS

Pressure from developments on the F3 Freeway at Wahroonga has accelerated the RTA's efforts to refine its concrete surfacing techniques. Overseas developments within the past 3 years have been closely monitored and trials have recently been conducted on the F3 Freeway at Wakefield, thanks to the initiative of the Northern Region's Major Projects Division.

These trials will be treated later in this paper, but by way of introduction, I will summarise overseas developments which prompted the local trials.

International Developments

Surfacings have received substantial research attention in the past 5 years, particularly in Europe, and there have been several developments which are of interest to the RTA's operations.

Surface profile

The Belgian Road Research Centre (BRRC) has isolated a profile characteristic of road surfaces which contributes significantly to many aspects of ride quality and vehicle response.

The traditional measures of surface irregularities have been microtexture, macrotexture and roughness. However, recent work has shown that irregularities in the hitherto unmeasured wavelengths of 50-100 mm have a significant impact.

This newly monitored roughness type has been termed "megatexture" and its definition has been extended to encompass all irregularities within the wavelength of 50 to 500 mm, thereby filling the gap between macrotexture and roughness. This development has application for all road surfaces but is particularly relevant to concrete pavements.

The influence of the four characteristics is shown in Fig 1 and can be summarised as follows:

- Microtexture and macrotexture cause only deformations in the tread of the tyre.

- Roughness produces deformation of the suspension system but only minimal tyre deformation.

- Megatexture lies in the wavelength which maximises tyre deformation beyond the contact profile which it would assume on a flat surface. The critical wavelength is actually one half of the footprint length of the tyre, which is generally between 50 and 100 mm for both cars and trucks. These wavelengths are not detected by the various roughness measuring devices and will not generally be detected by the sand patch test.

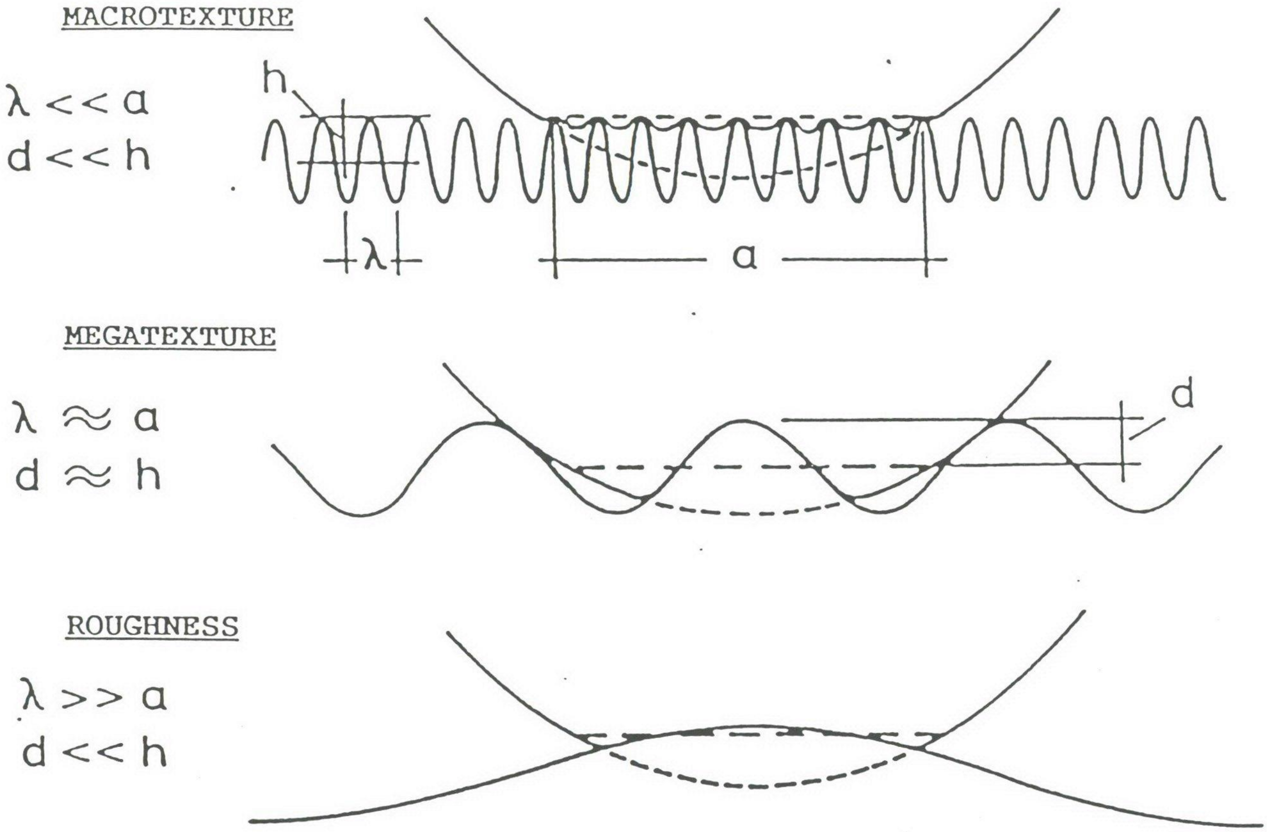

FIGURE 1 : EFFECT OF SURFACE PROFILE ON TYRE DEFORMATION.

(The horizontal broken line represents the profile which the tyre would assume on a smooth flat surface.)

(Belgian Road Research Centre, Brussels. Unpublished work by Mr Guy Descornet.)

The PIARC Technical Committee on Surface Characteristics now defines the various forms of irregularities as follows:

microtexture:	$\tau < 0.5$ mm
macrotexture:	0.5 mm $< \tau <$ 50 mm
megatexture:	50 mm $< \tau <$ 500 mm
roughness:	0.5 m $< \tau <$ 50 m

where τ is the wavelength

Megatexture is commonly seen in the following surfaces:

* Sprayed seals with variable size aggregates, and particularly in 2 size aggregates where the larger stone is too lightly spread.

* Surfaces deteriorated with alligator cracking, spalling, small potholes, plucking or stripping.

* Concrete, with even minor transverse irregularities caused by effects such as vibrating or surging in the paver, or by the action of the correcting beam. The *"super-smoother"* finishing float was designed to remove these irregularities.

Megatexture is now known to have a significant and deleterious effect on traffic noise, vehicle vibration and rolling resistance. Each of these nuisances can be noticeably reduced with even very small reductions in megatexture. These and other effects are shown in Fig 2. Significant aspects of these results are treated under.

In terms of rolling resistance, the worst wavelength appears to be approx 80 mm for speeds of about 50 km/h.

With regard to pavement loading, irregularities of even a minor amplitude can result in increases of 30-40% in computed equivalent standard axle loads because of the impact component. Critical frequencies lie in the range 1-30m.

Of the total noise emitted by a vehicle, the tyre/road interaction represents a major and sometimes dominant source at higher vehicle speeds. Contact noise can vary by more than 10 dB(A) with different surface characteristics.

- When irregularities with wavelengths near 80mm (ie megatexture) increase in amplitude, tyre noise increases, mainly in the low frequency part (< 1 kHz).

- When irregularities with wavelengths close to 3mm increase, the level of tyre noise decreases, mainly in the high frequency range (> 1 kHz). This is thought to be associated with suction noise ("air pumping") and is consistent with the observation that very smooth surfaces are noisier than those with a fine macrotexture or with open-textured surfaces.

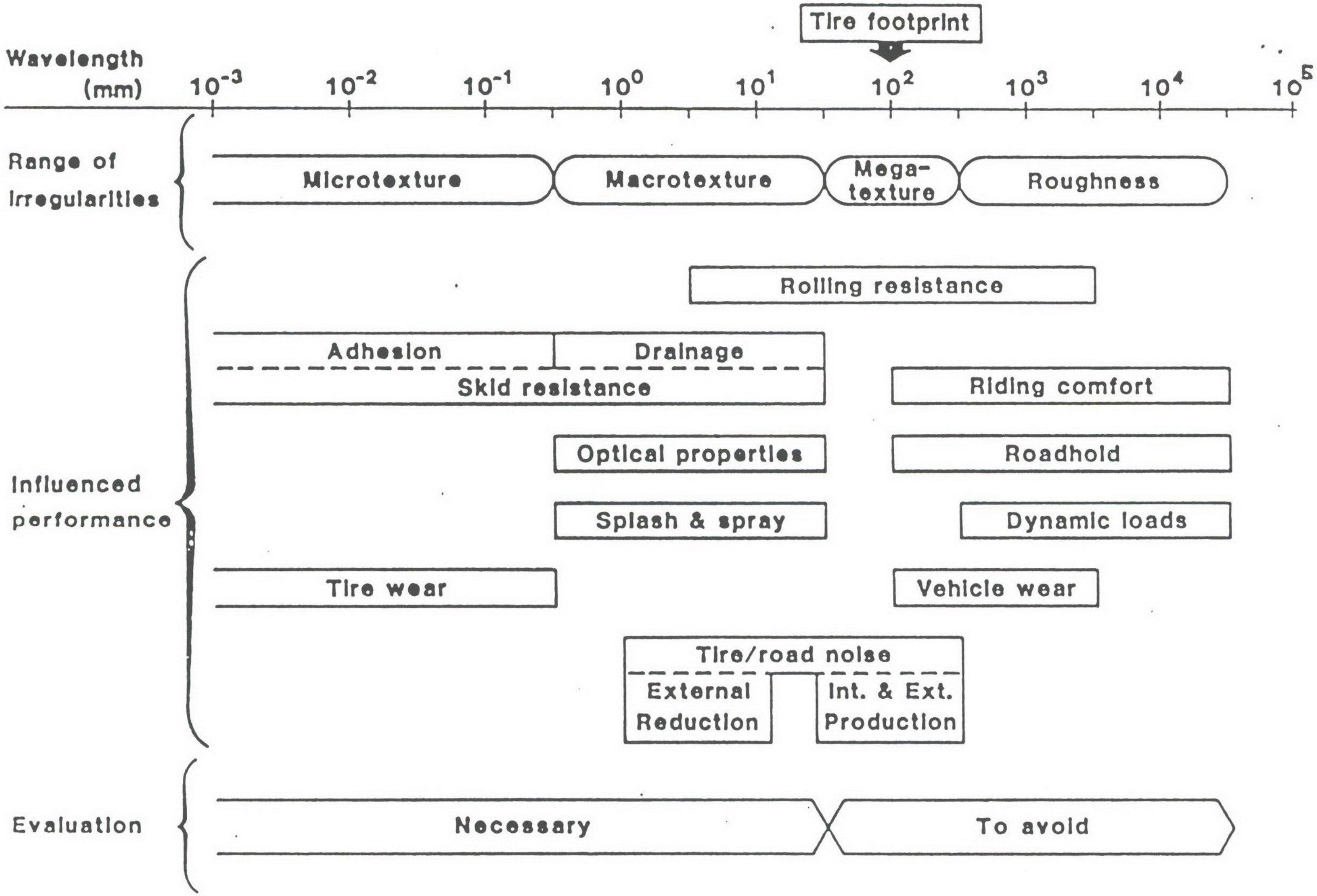

FIGURE 2 : INFLUENCE OF SURFACE PROFILE ON MEASURABLE DRIVING CONDITIONS.

(Belgian Road Research Centre, Brussels. Unpublished work by Mr Guy Descornet.)

Noise levels inside vehicles can vary by as much as 15 dB(A) with different pavement surfaces. Vibrations (as they influence comfort) in vehicles have been shown to be critical in the range 50 mm - 3 m.

The sensitivity of ride quality to varying surface profile is very apparent from observing the significant variations in noise generation and "harshness" of ride on discrete sections of the F3 Freeway between Mt Colah and Palmer's Rd. An intensive survey of this and other concrete pavements is now planned in order to isolate the characteristics which most contribute to these properties.

Surface texture

There have been few developments in this field since the early 1980's when significant research work was published by the Transport and Road Research Laboratory (TRRL) in England. It was this work which formed the basis for the RTA's current specifications for texturing.

However, the following issues are relevant to future consideration of amendments to our standards:

* TRRL research has confirmed that microtexture is the critical component for skid resistance, even at high speed. The effectiveness of the microtexture is largely dependent on the quartz content of the sand. The RTA's aggregate specification has long acknowledged this fact. Macrotexture is viewed primarily as a medium for quickly removing surface water so that tyre contact is maintained, thus ensuring optimum benefit from the microtexture.

* TRRL work has also shown that the mortar is the critical component in durability of friction. (TRRL Report RR144 refers) This leads to the conclusion that aggregates susceptible to polishing can safely be used as long as durability of the mortar is ensured. Durability depends substantially on cement content, water/cement ratio, and effectiveness of curing; all issues on which RTA specifications are justifiably strict.

* Surface texture in Europe is generally less harsh than ours. This reflects firstly a greater confidence in its durability, and secondly a confidence that modern tyre technology provides a significant safety margin in wet conditions over that which would be expected from conventional skid resistance testing with smooth tyres.

With regard to skid resistance, maximum effectiveness of drainage at tyre/pavement contact is achieved where irregularities have wavelengths of 8 - 16 mm. For maximum tyre grip (wet or dry) the vertical action of the wheel must be as steady as possible and critical (undesirable) wavelengths in this regard lie in the range 0.5 - 8m.

RTA SPECIFICATIONS

For rural concrete surfaces the RTA has typically specified a transversely tyned finish with an average texture depth of 0.3 to 0.65 mm as measured by the sand patch method. This corresponds to an actual groove depth of 1.5 to 3mm. A pattern of variable tyne spacings is specified to prevent tyre "humming". This surface provides very good skid resistance but noise generation is equal to that from dense grade asphalt, at a level about 4.5 - 6 dB(A) higher than open grade asphalt (OGA).

Within 80 km/h zones the RTA will normally specify a longitudinal hessian drag finish with no transverse texturing. Noise generation is 3 dB(A) lower than tyned concrete but 1.5 - 3 dB(A) higher than OGA.. At urban speeds, microtexture alone ensures adequate friction.

Highest priority for research effort is being devoted to the refinement of the rural texturing pattern. The RTA's current standard was derived largely from work in Britain and the United States.

Overseas developments in the past 2 years have encouraged the RTA to modify its practices in the following regards:

* *To reduce the texture depth in an attempt to reduce noise levels.* This accords with European trends over the past decade and stems from increased confidence in both the durability of good quality concrete surfaces and in the performance of modern tyres.

* *To provide a hessian drag finish in advance of the transverse tyning,* to enhance macrotexture (consistent with the above-mentioned research findings) in order to reduce noise, rolling resistance and wet spray whilst enhancing skid resistance.

* *To trial varying tyne widths and spacings,* again with a view to reducing noise generation.

Various combinations of the above variables have been trialled on recent work on the F3 Freeway north of Palmer's Rd at Wakefield.

Initial subjective assessment justifies optimism that subtle but significant improvements will be measurable in terms of reduced noise and "harshness" of ride.

Roughness readings on this project have consistently ranged from 27 to 32 counts/km with maximum values in the low 40's. This is the best result measured in substantial lengths since the early 80's and restores much of the confidence of that period that high standard finishes are achievable from competent contractors.

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DELINEATION

PROFILE LINEMARKING

TRAFFIC SECTION
CONSULTING SERVICES BUREAU
TECHNICAL SERVICES DIRECTORATE
ROADS AND TRAFFIC AUTHORITY
NEW SOUTH WALES

CONTENTS

1. INTRODUCTION

Delineation treatments are mainly visual aids that provide guidance, regulatory or warning information to the drivers in their driving task. However, the advent of Profile linemarking has changed, to some extent, the basic concept of delineation. Profile linemarking not only constitutes a visual aid but more importantly provides an all-weather audio-tactile warning to the drivers.

Limited field experience indicates that Profile linemarking holds promise as an improved short range delineation treatment. Better visibility and audio-tactile warning may provide improved lane tracking guidance to drivers. Raised Pavement Markers (reflective and non reflective) also provide limited audio-tactile warning but their poor retention and far spacing do not render them to be a reliable audio-tactile system.

2. BACKGROUND

Statistics indicate that a large number of road accidents occur where driver loses vehicle control. Included in the wide range of possible causes are the driver's loss of concentration, fatigue or failure of delineation system to provide adequate information about the lateral boundaries of the carriageway.

Pavement Markings provide vital information to drivers regarding lateral boundaries of the road to allow for proper vehicle placement and manoeuvre. Field practitioners are continually on the look-out for materials or systems that will provide improved guidance, especially under adverse weather conditions. Profile linemarking is one overseas development which RTA has recently investigated.

3. CHARACTERISTICS

3.1 GENERAL

Profile Linemarking is made up of ribs of thermoplastic material with a maximum height of about 10 mm, measured from the top of the road surface. Depending upon the type of method employed to lay these lines, the ribs may be placed, at a desired interval, directly on to the pavement surface or over the conventional thermoplastic line.

The major advantages of this type of linemarking are:

(I) BETTER WET-NIGHT VISIBILITY

Depending upon the thickness of water-film, the ribs of the Profile Linemarking stand out to a greater or lesser extent and allow water to drain off from the reflective face.

The glass beads on the reflective face then reflect the light directed towards them, back to the driver **(Figure 1)**. When viewed from a distance, the peaks of the ribs are seen as a continuous line.

(II) AUDIO-TACTILE WARNING

Profile Linemarking also provides an audio-tactile warning to the driver if the vehicle is running over the line. This vibrationary feedback should prevent the driver from straying from the lane or the carriageway.

3.2 TYPES

Profile Linemarking is applied either by *screeding* or *extruding* thermoplastic materials.

In the *screed technique*, hot thermoplastic material reaches the applicator shoe by gravity. The gate of the shoe is opened to a preset gap to form the width and thickness of the line. The applicator shoe is dragged forward to lay the line.

Extrusion is a process, where thermoplastic material is extruded, under pressure, through a slit of predetermined size.

Although the screed and the extrusion techniques are slower than spraying, <u>they provide lines with sharper and clearer edges</u>.

Currently the Profile Linemarking can be laid in by three commercial methods:

(A) VIBRALINE
Vibraline (A British method) uses a special grade of thermoplastic material. It is formed by mechanically screeding a conventional thermoplastic line and simultaneously applying transverse ribs of same thermoplastic material at a regular interval.

The screeded line is about 2 mm thick and the ribs are about 8 mm high (10 mm from the road surface). The frequency and configuration of ribs can be varied to suit any requirements, however, 250 mm is considered to be the most optimum spacing.

The glass beads are premixed, however, the marking is completed by pressurised surface application of glass beads to provide immediate retroreflectivity.

Vibraline is applied by equipment, especially designed and built by PRISMO Ltd., U.K. The application speed of the machine is about 8 km/h and the curing time of the lines is about 20 minutes,

The lines can be laid in 100 mm, 150 mm, 200 mm widths.

(B) FRENCHLINE
Frenchline (A French method) also uses a special grade of thermoplastic material. Frenchline is also formed by mechanically screeding a conventional thermoplastic line and simultaneously placing transverse ribs of same material at a regular interval.

The screeded line is about 2-3 mm thick and the ribs are about 8 mm high (10 mm from the road surface).

The glass beads are premixed, however, the marking is completed by the pressurised application of glass beads to provide immediate reflectivity.

> *The main difference between Vibraline and Frenchline is in the shape of the ribs. Vibraline places twin transverse ribs at a time with a gap in-between. Frenchline places single rib at a time across the entire width of the line* ***(figure 2 and 3).***

Frenchline is applied by equipment, especially designed by Euroliners, France. The application speed of the machine is about 12 to 15 km/h and the curing time of the lines before they could be opened to traffic is about 20 minutes. The Frenchline can be laid in 100 mm, 150 mm, 200 mm widths.

(C) ZAGANITE LINE
Zaganite line (A Danish method) is formed by mechanically extruding ripples of thermoplastic material with premixed glass beads. The material is not placed as a continuous line but applied in the form of either intermittent bar or checker plate patterns of about 2-3 mm thickness **(Figure 4)**.

The patterns are computer controlled and can be varied. A typical bar pattern is a 50 mm profiled bar and a 50 mm gap. A typical checker plate pattern is an alternative sequence of 25 mm squares with a profile and a gap.

The line can be laid in 100 mm, 150 mm, 200 mm and 500 mm widths.

The Zaganite line is applied by a Danish machine and application speed is about 12-15 km/h. The curing time of the lines is about 20 minutes.

4. PROFILE LINEMARKING TRIALS

4.1 OBJECTIVE

(a) To assess its **EFFECTIVENESS AS A DELINEATION TREATMENT** under following conditions:

- Fine and adverse weather conditions,
- Varying visibility conditions, viz., day, night, and glare from headlights.
- Different traffic situations and road geometry, viz., edgeline, centreline, lane line and continuity line (with various line widths) and in curve sections, tangent sections and turning bays (S lanes).

(b) To **COMPARE ITS PERFORMANCE WITH CONVENTIONAL PAVEMENT MARKINGS**, viz., as a delineation treatment, material, cost, maintenance, ease of application and the applicability over different pavement surfaces.

(c) To **COMPARE THE PERFORMANCE OF THE THREE COMMERCIAL METHODS OF PROFILE LINEMARKINGS.**

(d) It was also intended to study the **EFFECTIVENESS OF THE 'AUDIO-TACTILE' EFFECT** of the Profile linemarking as measure of creating better lane discipline and also to examine whether the noise created by the tyres, running over the ribs is environmentally safe.

(e) To study the effect of Profile linemarking on the **ACCIDENT TRENDS** at the trial sites.

4.2 TRIAL SITES

LOCATION	WIDTH	LENGTH	TREATMENT
A) F3 FREEWAY, Mt. White-Hawkesbury River Bridge (A/C)	150 mm	1.5 Km each side	Edgeline (VIBRALINE)
July 1990	150 mm	5 Km each side	Edgeline (ZAGANITE)
B) GREAT WESTERN HIGHWAY, Linden(A/C)	150 mm	1 Km each side	Edgeline (VIBRALINE)
June 1990	100 mm BB line	1 Km	Centreline (VIBRALINE)
C) PACIFIC HIGHWAY	150 mm	3.8 Km	Lanelines(VIBRA) (S lane)
North Sydney-Wahroonga (A/C&C.C) July-Aug 1990	200 mm E4 line	2.6 Km	Outline of the painted median (S lane) (VIBRA)
D) SOUTHERN CROSS DRIVE Mascot (A/C) July 1990	150 mm	1 Km	Edgeline(FRENCH)
E) PENNANT HILLS	150 mm	1 Km	Edgeline(VIBRA)
ROAD	100 mm	2.2 Km	Centreline(VIBRA)
N Parramatta-	100 mm	2.2 Km	Lane line(VIBRA)
Carlingford (A/C) Nov-Feb 90-91	200 mm	1.7 km	Turning bays(VIBR) (S lane section)

There are several other sections of the road in NSW that have been treated with Profile linemarkings such as sections of the Great Western Highway, Katoomba; Victoria Road, Parramatta; Cumberland Highway deviation, Guildford; James Ruse Drive, N Parramatta; F5 freeway, Glenfield; Mitchell Highway, Orange and Dubbo; Hume Highway, Goulburn; Dandaloo Road, Narromine etc. However, this report does not include the performance of Profile linemarking on these locations.

5. OBSERVATIONS

(a) Effectiveness as a delineation treatment

- Profile linemarking fulfils the basic 'driver information needs' of maintaining the lateral placement of the vehicle within the traffic lane (short range information).

- Profile linemarking is fairly conspicuous under day and night conditions. However, discolouration due to tyre marks is noticed to have occurred where profile linemarkings are subjected to high turning movements and where narrow lane widths occur in heavy braking areas. This, to some extent, has affected the visibility of the markings.

- Profile linemarkings are visible under light to moderate rain. They too can be obscured under heavy rain. However, the audio-tactile warning under such conditions compensates for this to some extent.

- Profile linemarkings are not a completly effective substitute for RRPMs in wet-nights. They, despite the ribs, need to be supplemented with reflective RPMs in some applications.

- Profile linemarkings do not show significant improvement in their noticeability under headlight glare or acute sun angles.

- Profile linemarkings from the limited field trials have proved to be useful as an audio-tactile device to sleeping motorists. Some of the drivers have reportedly corrected their straying movements after driving over the line.

- Profile linemarking may be useful as a deterrent to erratic movements in sections with sharp curves, high incidence of fog and adverse weather and sections containing fatigue zone.

- More than the much advocated improved visibility, the audio-tactile warning is the single most significant factor of the profile linemarking by virtue of which profile linemarking is generally noticed by the motorists. It is not surprising that the majority of drivers do not notice these lines on wide carriageways such as on F3 freeway unless they cross them and experience the audio-tactile effect.

- Performance of profile linemarking on freeways is currently monitored as a substitute to simulated lane lines. Besides providing similar audio-tactile warning, profile linemarking may provide superior night-time visibility of lane lines compared to ceramic markers.

. Profile linemarking on turning lanes (S lanes) does not greatly improve the conspicuity of the lanes. However, the audio-tactile warning does make motorists aware of the turning lane under adverse weather conditions. Wearing (flattening) of the ribs in such locations is significant.

(b) Performance compared with conventional pavement markings

Visibility of conventional painted lines under fine day and night conditions is similar, if not better than the profile linemarkings. It is in the wet, when specular reflection is high, that profile linemarkings are more conspicuous. Additionally they enable the motorist to sense the carriageway boundaries with the audio-tactile warning.

. Profile linemarkings have been claimed to have life up to six years under ideal conditions. However on the turning bays and narrow sections, one year after the application profile linemarkings have noticeably worn out and ribs considerably flattened especially on narrow single carriageways-two way roads.

. Relative characteristics of conventional paint and profile linemarkings are given below.

	Conventional Painted Line	**Profile Line**
Dry thickness (mm)	.2 to .3	2 to 3 with 8 mm ribs (Vibraline and Frenchline)
Solids content (% by volume)	50	100 in thermoplastic
Average application rate	.3 litres/sq m	4 to 8 kg/sqm
Average glass bead application	750 gm/m	300 gm/kg
Average cost	$3/sq m	*Zaganite* (i) $10/sq m *Vibraline* (ii) $23.5/sq m
Equipment travel speed	20-30 km/h	8-15 km/h
Volatile organic compound	377 gm/litre	0
Typical comparative life	6 months	4 years(Zaganite) 6 years(Vibraline)

(c) Profile linemarking methods compared

Vibraline and Frenchline are similar in the pattern and application method. Both lines are firm thermoplastic lines and ribs (8 mm high) across the width. Zaganite line is a broken line with the ribs (2-3 mm high) or profiles directly placed on the pavement surface.

- Since the ribs in the Zaganite line are only 2 to 3 mm high, they are not as effective as the other profile lines as far as visibility and audio-tactile performance are concerned. However, Zaganite lines are less costly and have lower curing time.

- Zaganiteline's suitability, from the legal point of view as a broken edgeline (Motor Traffic Act requires edgeline to be unbroken line) is questionable. Moreover, Zaganiteline's bar pattern needs to be investigated further as it may, in some cases, confuse the motorist with the continuity line.

- Limited application of Frenchline, applied as an edge line on a freeway section has shown considerable promise. The line after one year of application has not shown significant sign of wear. However, as mentioned earlier, the lines in freeway conditions are subjected to less traffic wear.

- Relative effectiveness of Profile linemarking comparing the parameters of visibility, audio tactile effect and versatility of application in different traffic situation (lane line, edge line, centre line and continuity line) indicate that Vibraline holds a clear edge.

(d) Audio-tactile effect

- As mentioned earlier, the all weather audio-tactile warning of the Profile linemarkings is the single most outstanding feature.

- This feature may particularly be useful in alerting sleeping or fatigued motorists or checking straying movements of drivers impaired by alcohol.

- Of increasing interest to all highway users and traffic engineers is the effect of audio-tactile noise on the environment. Several applications of Profile linemarking have been in urban areas and so far no adverse reports from the residents have been received.

  Trials to evaluate the noise emitted from Vibraline profiled road marking was carried out using three types of vehicles on *Motorway and Highway sites in England on 25 June 1990.*

  Vibraline dimensions with rib centre spacing of 250 mm and 500 mm were monitored using noise detection meters which recorded noise in decibels.

Noise levels were recorded at three points:

(1) Within the vehicle
(2) Close to the left hand edge line
(3) 15 metres away from the hard shoulder and 2 metres above the road

Vehicle speeds ranged from 50-80 miles per hour (80-128 km/hour).

The following conclusions were reached from recorded noise levels:

Noise detected inside the vehicles

Noise levels detected inside the passenger compartment from Vibraline with rib centre spacing of 250 mm and 500 mm were found to be significant enough to be heard by drivers with average hearing.

Increases in noise levels recorded inside the pick-up and truck when driving on Vibraline, whilst lower than increases for cars, was still considered sufficient to be recognised by the driver.

Noise detected outside the vehicles

Noise levels recorded at the roadside were found to be significant enough to warn a person with normal hearing of the close proximity of a vehicle. Noise level increases recorded 15 metres away from the hard shoulder and 2 metres above the road surface were not considered significant enough to be detected by a person with normal hearing above the general traffic background noise.

(e) **Accident Analysis**

It is too early for the accident record on the trial sites to exhibit any definite trend. However, a before and after study of raised rib markings installed on nine lengths of the M4 in Berkshire, UK, 6 km in all, all sites coinciding with the termination of long left-hand bends - found that all accidents at the treated sites were reduced by 38 per cent, from 45 in three years to 28 in three years (significant at the 2.5 per cent level). Accidents involving vehicles leaving the nearside of the carriageway reduced by 76 per cent, from 29 in three years to seven in three years (significant at the 0.5 per cent level). The percentage of accidents involving vehicle leaving the nearside carriageway at treated sites reduced from 66 per cent in the three years after treatment, 1985-87. At untreated sites the percentage remained reasonably constant, at 46 to 48 per cent. Profile markings have the potential to be a very effective accident remedial measure if the savings reported by Berkshire are repeated in NSW.

6. EVALUATION

Effectiveness evaluation was carried out to compare four alternative linemarking treatments of 100 mm edge line on a two lane two-way rural road. The methodology used here is discussed in detail in the forthcoming delineation guide. It relies heavily on subjective judgements due wide variety of variables involved. The values are only helpful in relative comparision of the treatments. The actual merit i.e. the accident reduction must be considered as the final proof. The summarised values are presented in **Table 1.**

7. CONCLUSIONS

Traffic and road user safety has become a very important issue in highway engineering. Profile linemarking promises to be a cost-effective means of providing for traffic and road user safety.

Apart from improved visibility under adverse weather conditions, one of the significant advantages of Profile linemarking relates to its audio-tactile stimulus. Sound emitted by the vehicle moving over the raised ribs is perceptible to persons both inside and outside the vehicle.

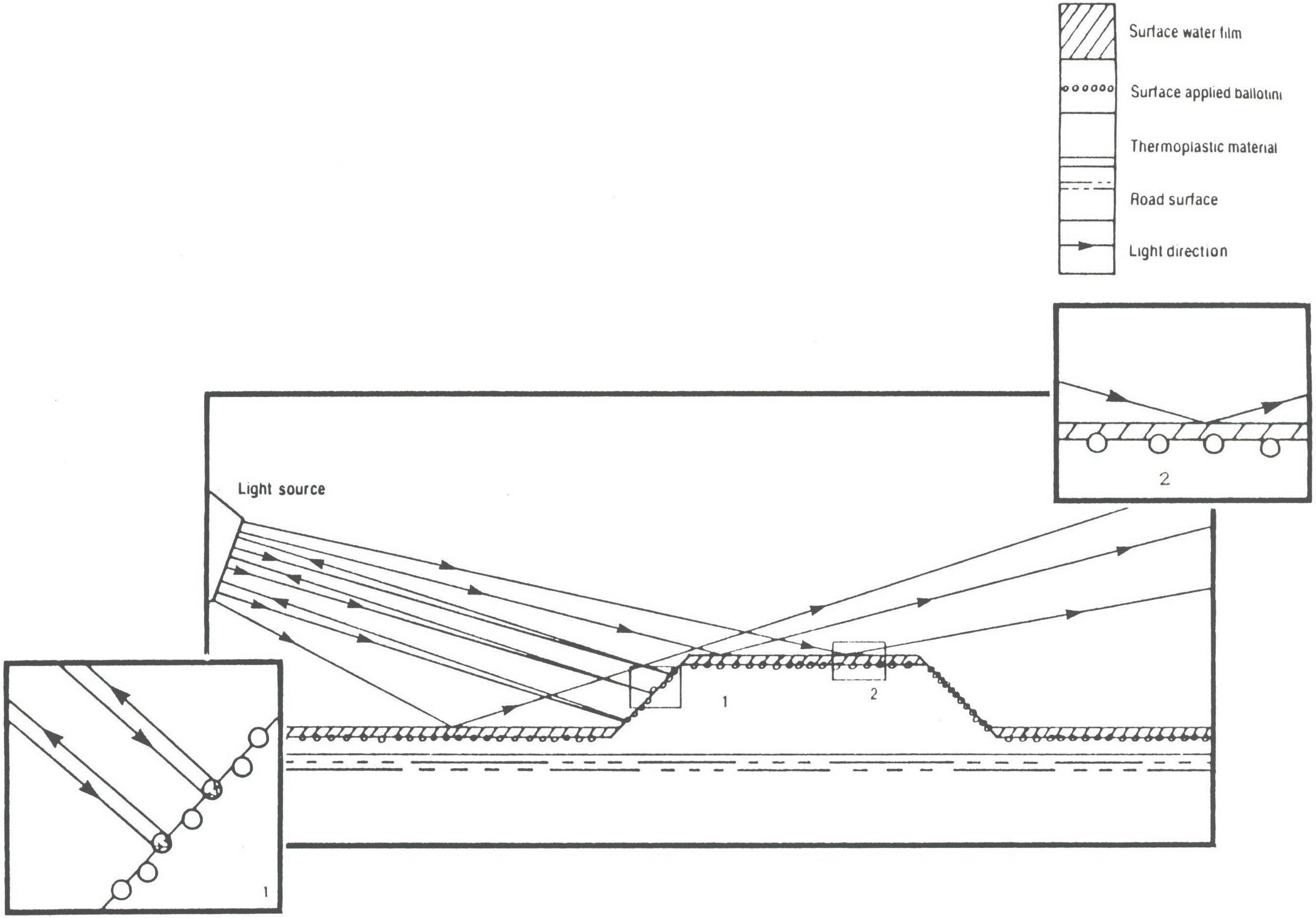
The benefit of audibility of the sound to the road user besides the driver is that it can act as a warning of impending danger to pedestrians and cyclists.

Studies conducted in the UK indicate that accidents at the treatment sites were reduced by 38% from 45 in three years to 28 in three years.

Environmental studies also indicate that the level of sound generated by the audio-tactile affecting the lines is not so high as to disturb residents living near the road marking.

TABLE 1

SITUATION *100 MM EDGE LINE* *2 LANE RURAL ROAD*	MERIT MEASURES							MERIT RATING	EQUIVALENT ANNUAL COST PER KM	MERIT COST RATIO
	EFFECTIVENESS RATING AS A DELIN. TREATMENT	APPLICABILITY OVER VARYING CONDITIONS	ADVERSE WEATHER EFFECTIVENESS	INDIRECT BENEFITS	FREEDOM FROM MAINTENANCE	EASE OF IMPLEMENTATION	CONSISTENCY WITH STANDARDS			
TREATMENT	WEIGHTS									
	35	*10*	*15*	*15*	*10*	*10*	*5*			
PAINTED LINE	3	10	3	5	3	10	10	1890	590	**3.2**
VIBRALINE	10	8	10	10	8	6	8	3490	461	**7.5**
FRENCHLINE	8	6	8	8	10	6	8	2990	461	**6.5**
ZAGANITELINE	4	1	4	6	6	7	1	1630	276	**5.9**


Surface water film
Surface applied ballotini
Thermoplastic material
Road surface
Light direction
Light source
1
2
2
1

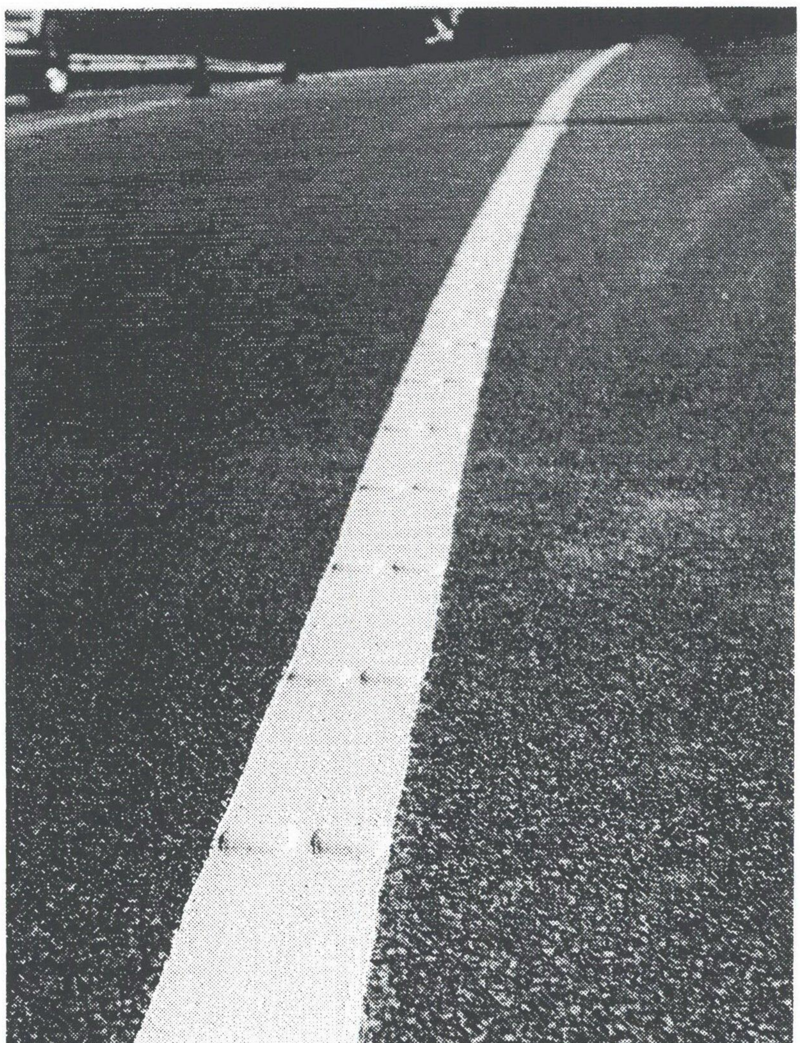


Fig. 2

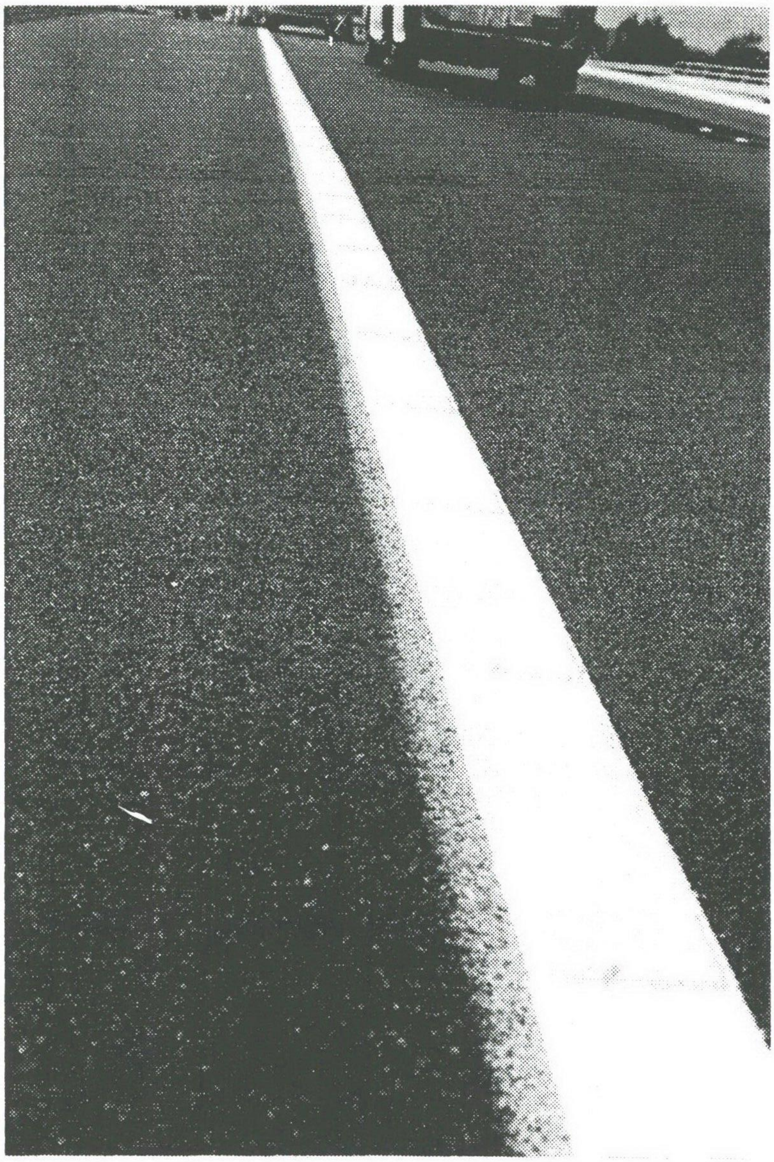


Fig. 3

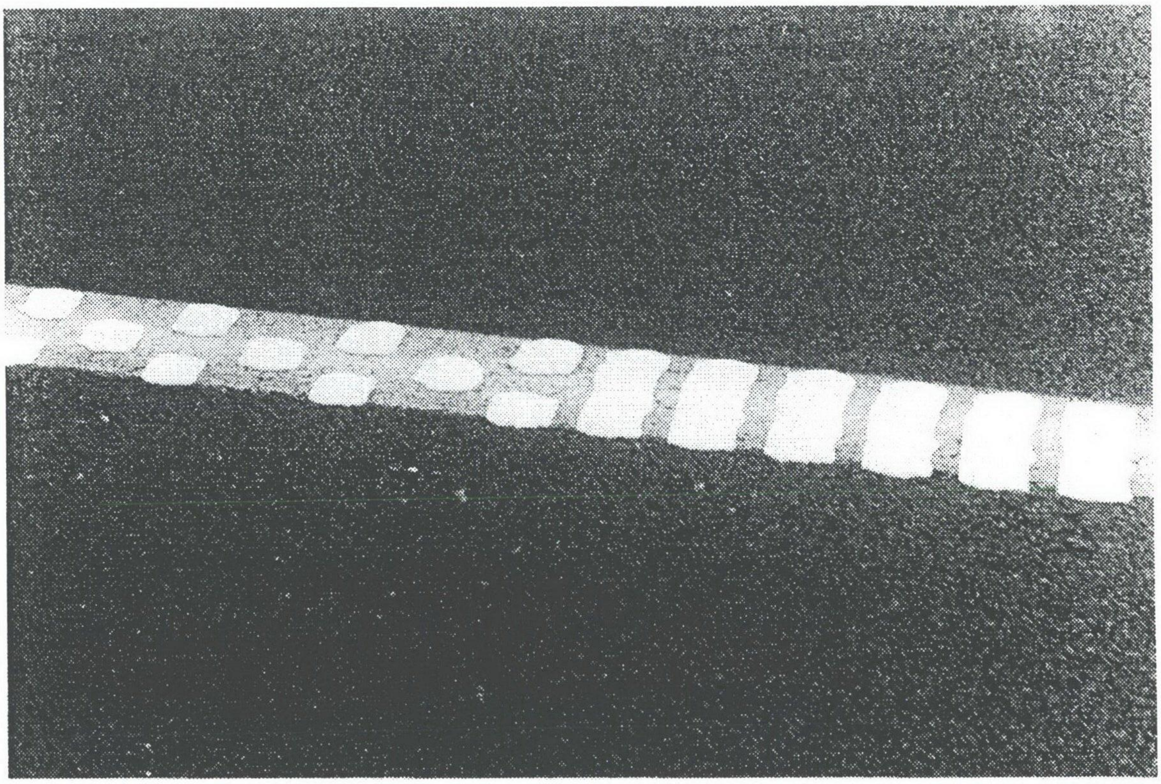


Fig. 4