Road Construction Authority
Technical Activities Report

1983/84

Road Construction Authority
An Authority of VICTORIA TRANSPORT

Technical Activities Report

of the Road Construction Authority 1983-84

This Technical Activities Report, which supplements the Authority's Annual Report 1983/84, presents information on a number of technical activities during the year which are considered to be of general or specific technical interest.

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Contents

Repairs to Bridge Deck Expansion Joints – Hume Freeway

During the period 1980 to 1983 problems associated with transverse deck expansion joints, particularly in the left lane, on structures on the Hume Freeway between Wandong and Broadford became evident.

Replacement of a number of the existing joints has been carried out and a program of further replacements is in hand. Generally these structures have transverse expansion joints consisting of steel angles cast into the concrete decks and preformed neoprene seals to span the gaps.

In the construction of these joints it is difficult to properly place the wet concrete under the horizontal flanges on the steel angle sections, and cavities in the hardened concrete generally occur. The impact and pounding of truck tyres work the angles loose and eventually the steel anchor straps break and the angle sections break. Remedial repair work usually requires the complete reconstruction of the expansion joints and replacement with continuous gland-type joints such as Felspan or the Wabo Elastoflex joints. Refer to Figures 1 and 2.

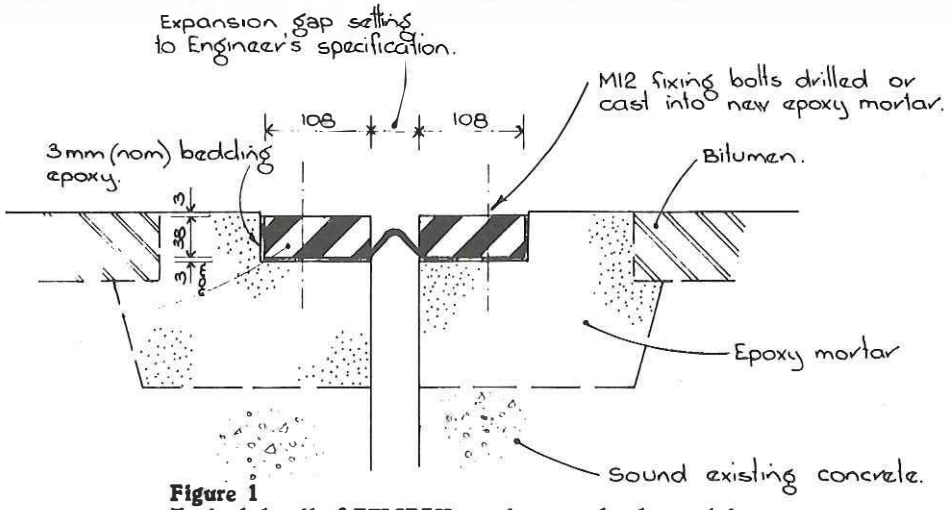


Figure 1
Typical detail of FELSPAN continuous gland-type joints

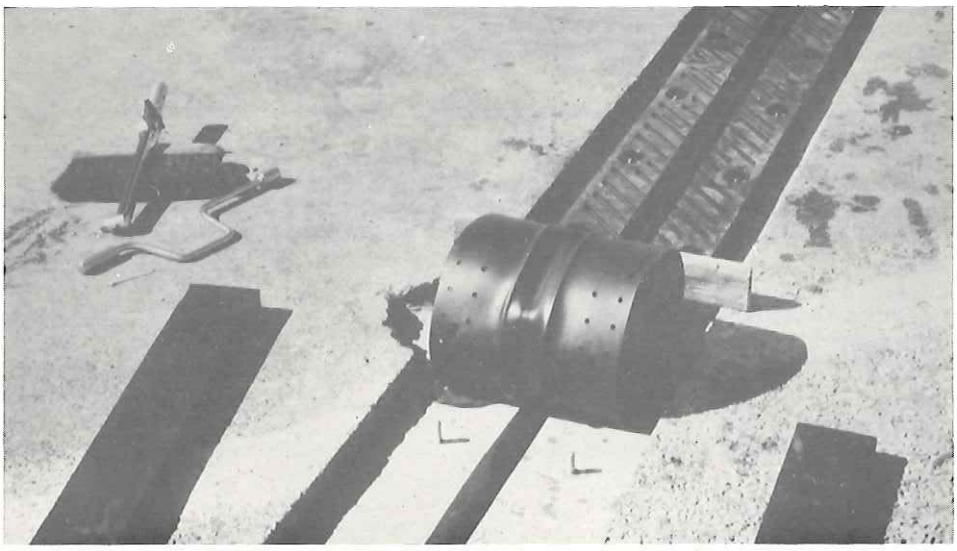


Figure 2
Rolling out gland and placing pads

Since installation, the continuous gland-type joints have performed satisfactorily. They have been relatively simple to install. The neoprene pads appear to cushion tyre impact loads protecting the epoxy mortar from damage.

Bridge Instrumentation

During the year a number of bridges have been instrumented to measure strain and deflection. Generally the need has arisen from the desire to learn more of the behaviour of structures in relation to design codes and to observe the response to very heavy permit loads.

A compact micro processor controlled commercial data logger has been used for this work. A dual constant current power supply is employed ensuring very high accuracy when used with electric resistance strain gauges and the long leads necessary in the field. The micro processor handles the complex computation necessary with this form of power supply and enables direct display of strain in the office. A micro-computer has been used for this purpose coupled to a graphics plotter and printer for reporting of results.

Gauges used have been either embedment type, cast into the structure during construction, or externally adhered using epoxy adhesives in the case of concrete or weld on metal gauges in the case of steel. Deflection measurements have generally been monitored using potentiometric transducers attached between the structure and a reference scaffold on the ground.

The compact reliable loggers together with improved strain gauge techniques have led to installations having success rates of obtaining useful data of almost 100%.

Super Plasticised Concrete for Bridgeworks

Chemical admixtures based on lignosulphonates, hydroxy carboxylic acid salts and processed carbohydrates have been used as plasticising or water reducing agents for over thirty years. During the last ten year admixtures consisting of aqueous solutions of sulphonated derivatives of melamine formaldehyde or napthalene formaldeyde have become available. The chemicals are now generally referred to as superplasticisers and have been used for the last four years in selected bridgeworks.

When added to concrete mixes these admixtures act as dispersing agents, and allow reductions in water to be achieved while maintaining the level of workability of the concrete. These superplasticisers can be useful in two ways:

(i) to produce high strength concrete with acceptable levels of workability;

(ii) to produce flowing concrete by imparting extreme workability to normal concrete mixes.

The enhanced flowing property brought about by the addition of superplasticers to concrete is of interest in the manufacture of precast concrete components and in the compaction of concrete in confined spaces. Investigations have shown that superplasticising admixtures can be used with beneficial results in these areas.

(i) **Precast concrete Components:**

Superplasticisers have been used in the manufacture of long slender post tensioned hollow beams designed with closely spaced steel reinforcement and with three or four tendon ducts for stressing cables. These beams form part of the superstructure of many pedestrian overpasses and require a high strength high slump concrete. The internal void is formed with blocks of polystyrene material which is left in place after concreting. With normal high strength concrete it has been found difficult to place concrete below the polystyrene at the soffit, around the tendon ducts, and in heavily reinforced areas. Superplasticiser additives in concrete solve the problem by providing greater workability without reduction in concrete strength. The characteristic has also been found to be valuable in the manufacture of high quality "I" beams.

(ii) **Cast-in-Situ Concrete:**

The addition of superplasticiser to concrete placed in the confined spaces of the webs of cast-in-situ box girders has been successful in preventing the development of holes and air pockets in the hardened concrete. However, care has to be exercised in the operation of vibrators in order to avoid segregation of concrete aggregates.

(iii) **Repairs**

During the year the bridge on the Heidelberg–Eltham Main Road over the Diamond Creek in the Shire of Eltham was widened and strengthened. The existing concrete beams had steel plates bonded to the tension flange to increase their load capacity and additional reinforced concrete was cast around the diaphragms and ends of the beams.

The bridge could not be fully closed during repairs, and the effect of traffic on part of the bridge had to be considered in designing the repair system. A rapid hardening material was required so that normal traffic could soon be restored as each section was strengthened. Laboratory trials were done on epoxy concrete, magnesium

phosphate concrete, high alumina cement concrete and superplasticised cement concrete and the superplasticised concrete was chosen because of its satisfactory performance and the relative ease with which it could be placed in the forms.

Concrete was supplied to the site in small mini mix trucks and superplasticiser added to produce a flowing consistency. Concrete was poured through a funnel in a 75mm hole drilled through the deck and flowed directly into the forms when it was compacted by a minimum amount of vibration directly on the form. A strength of about 25 MPa was achieved in about 2 days when that section could be opened to traffic again.

Superplasticiser additives to concrete have now become acceptable as an aid to placing concrete in selected areas of bridge construction provided their use is accurately controlled.

Epoxy Resins in Bridge Construction

Epoxy resins are gaining wider use in bridge construction and tests have been developed to evaluate their performance. In the past, epoxies have often been used to make bearing pedestals and in general repair and restoration work on concrete, but they are now being used as an adhesive for segmental box girder bridges. They therefore require evaluation and assessment in a similar manner to other structural materials.

Tests on pot life, open time, adhesion performance and other physical characteristics are now being carried out over a range of temperatures likely to be encountered in the field, and approval for use of a particular set of compounds on the West Gate Freeway bridges will depend on the results of these tests. There will also be extensive checking of the epoxies on site, using similar testing procedures, to monitor the performance of the materials being used in construction.

Special tests have also been devised where epoxies have been used in particular repair work on bridges. Steel plates have been bonded to tension flanges of concrete beams to increase their load capacity, and samples of this steel were epoxied to concrete cubes on site, and the bond strength measured by a compression test done on the specimen in the laboratory.

Precast Reinforced Concrete Culvert Crown Units

A new series of standard precast reinforced concrete culvert crown unit designs is being developed to replace the existing designs which have been in use since 1973.

The existing units cover a range of spans from 1.8m to 3m and heights of up to 3m in conjunction with depths of filling of up to 2.4m. Both the existing and the proposed crown units are 1.2m long measured parallel to culvert centreline.

The principal objective in developing the new units has been to achieve improved cost effectiveness, but the practicability of introducing larger spans and providing for greater depths of filling has also been examined. To meet these objectives, cross-sections incorporating tapered legs and haunched soffits and requiring reduced quantities of reinforcement have been developed to provide the required strength in the highly stressed regions at the corners of the units.

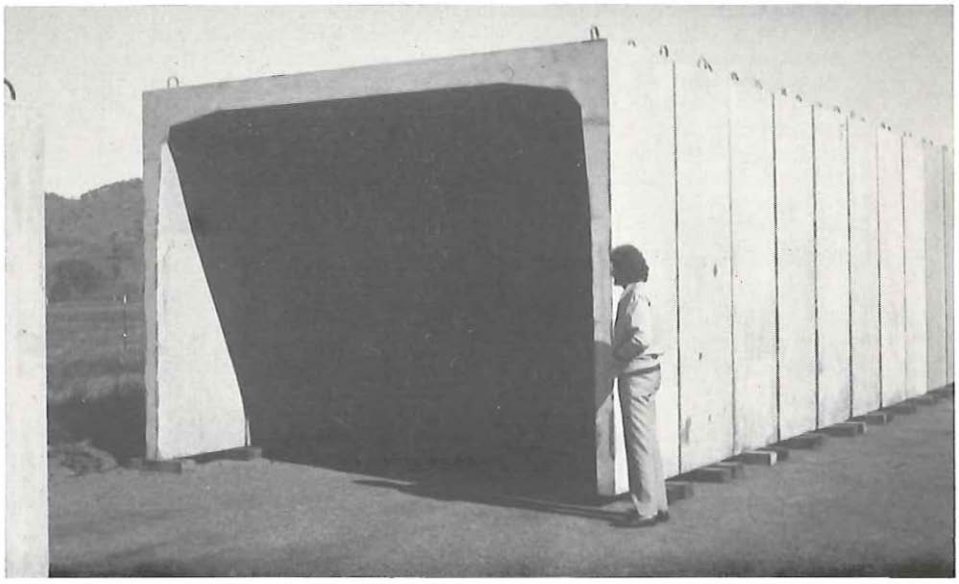


Figure 3
Precast reinforced concrete culvert crown units to be used on the Hume Freeway – Chiltern to Barnawartha section

The proposed range of crown units incorporates the following features:

- Haunches and tapers remain constant throughout the range of sizes thus simplifying formwork.
- Overall widths and heights of units in the range 1.8m to 3.0m span are identical to existing units, thus allowing use of new units to extend existing structures.
- Link slabs may be incorporated in multi cell culverts.
- The range of spans will extend up to 6m.

The first use of the new units has been associated with extension of a number of existing subways under the Hume Freeway, Chiltern to Barnawartha Section; refer to figure 3.

Dynamic Testing of Piles

About 18 months ago, the RCA acquired a full technology package from a firm of U.S.A. Consultants to carry out dynamic testing of piles. The Consultants had developed a simple method of pile instrumentation and a computer hardware and software system which for the first time allowed a closed form solution of the Wave Equation to be obtained.

The Wave Equation has been recognised for about 20 years as the most accurate model of the behaviour of a pile during driving. It allows the static resistance of the soil to be separated from the dynamic resistance. Earlier forms of dynamic equations used by the RCA to check on pile capacity during driving, such as the Hiley Formula, do not allow for this separation, and can sometimes give misleading results.

Development of a set of strain gauges and accelerometers which can be rapidly bolted to the top of a pile, has led to this breakthrough (see figure 4). The gauges allow the force in

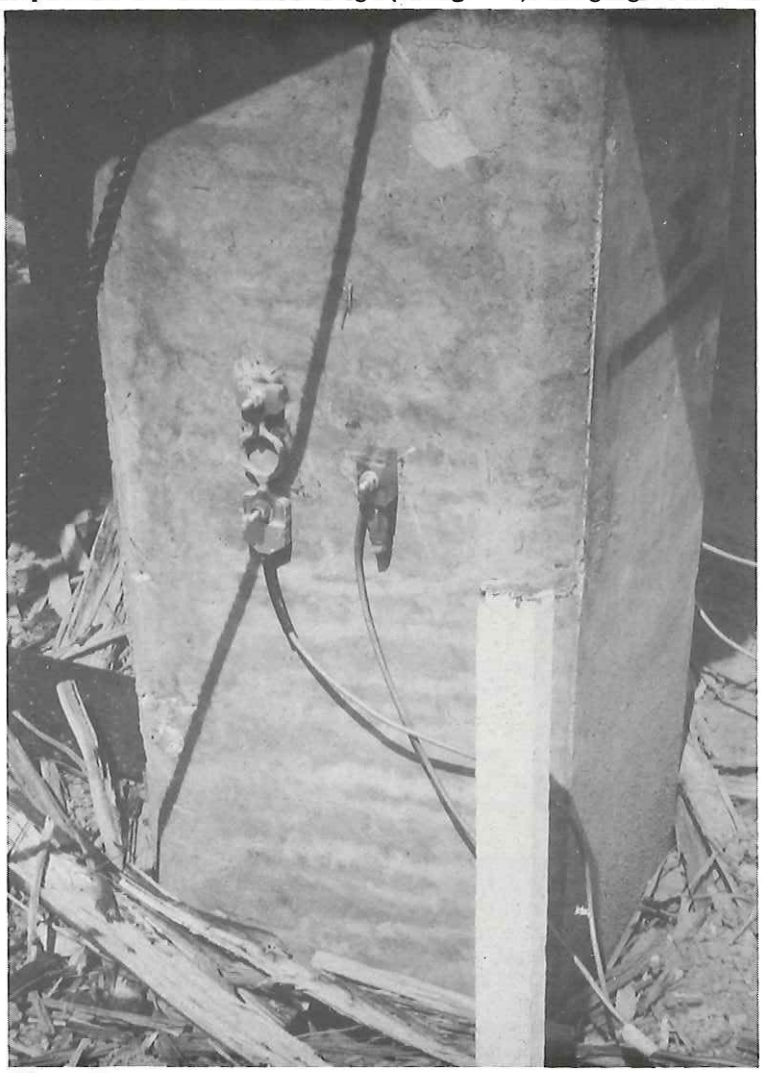
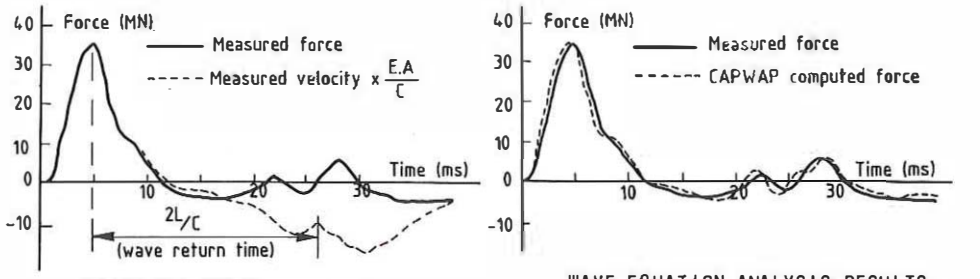


Figure 4
Accelerometer and strain gauge attached to head of pile



FORCE AND VELOCITY TRACES OBTAINED FROM FIELD INSTRUMENTATION

WAVE EQUATION ANALYSIS RESULTS SHOWING MATCH OBTAINED BETWEEN MEASURED AND COMPUTED FORCE TRACES

Figure 5
Field measurements and CAPWAP analysis balance

the pile at any time after the impact of the driving hammer to be measured. The force is related through the Wave Equation to the acceleration of the impacted shock wave which travels down and back up the pile, and this acceleration is also measured. By comparing the response measured by both sets of gauges with that calculated using the computer program CAPWAP, a balance can be obtained (See figure 5). From this balance, additional analysis can follow to provide information such as ultimate load—settlement curves, load-pile set curves on driving, hammer-cushion operating efficiency, and bearing graphs to assist pile driving supervisors to decide when the required pile load capacity is achieved on site.

The equipment is powerful, and fast to use. The normal procedure is to carry out a full CAPWAP analysis on one or two piles at a particular site. This involves collecting data during driving through an Analyser (this takes about ½ hour preparation to fix the instruments to the pile before driving, then taking measurements during the driving).

The data is put through a micro computer (approximately ½ day per pile). This analysis sets the soil parameters for the site. These can be used in a closed form solution analysis (the CASE analysis method) which is a short cut method etc., employing the Analyser on site to provide immediate answers on pile capacity on individual instrumented piles during driving. The site measurements can also be interrupted to check for any damage or lack of integrity in the pile.

The RCA performed dynamic testing with this equipment on conventional reinforced concrete driven piles at three projects during 1983/84. An extensive test piling program at the Hume Freeway, Baddaginnie to Bowser Section, Broken River bridges concluded that pile lengths designed using conventional static analysis could be shortened, with a potential saving of $83,000. Dynamic testing of piles driven into stiff fissured basaltic clays in the Princes Freeway East Warragul Section also showed that piles could be shortened, and at the Warragul-Korumburra Road Overpass a saving in pile length costs of $16,000 was realised.

The use of dynamic testing is increasing the RCA's understanding of pile behaviour during driving and allowing conventional static design methods to be refined. The RCA has the only complete facility for carrying out this testing in Australia and the equipment is in demand from other Road Authorities, Government Departments and Consulting Engineers. During the year, RCA Geotechnical engineers performed dynamic testing for six outside projects in Victoria, N.S.W., W.A. and Tasmania on a commercial cost basis.

Flood Estimation for Ungauged Rural Catchments
(Development of an Improved Method)

The 1982-83 Technical Activities Report discussed the need for improved methods of flood estimation, and indicated that investigations have been commenced to that end. These investigations have been carried out by an engineer on the staff of the RCA under the direction of Professor T A McMahon, Professor of Agricultural Engineering at the University of Melbourne.

Initially it was intended that a regional method of flood estimation would be developed covering all of those parts of Victoria which would be amendable to such an approach. However it subsequently was concluded that it would be prudent to reduce the size of the study region to allow more detailed examination of alternative methods of flood frequency analysis and flood estimation, the objective being to establish the appropriate methodology first, and to extend the area of its application later. The south-eastern region of Victoria, including the whole of Bairnsdale and Traralgon and part of Dandenong Divisions, was chosen because the stream flow records for that area were of comparatively long duration, and were not affected significantly by the presence of storages.

A regional approach was adopted, bearing in mind that the method evolved would be used largely in waterway design associated with bridges and culverts, and that estimates of

instantaneous discharge at given probabilities of exceedance were required, but not hydrograph shape. It was therefore necessary to establish relationships between probability of exceedance discharge Q_p, and climatological and physiographic catchment characteristics for regions considered to be hydrologically homogeneous.

Following an extensive review of work done by others in investigation of alternative regional methods, the procedure by which separate regression equations are derived for each selected probability of exceedance discharge Q_p in terms of definable catchment characteristics for each hydrologically homogeneous region was adopted; this is referred to as the "statistical estimation of Q_p procedure."

The stream flow data used for flood frequency analysis comprised maximum instantaneous discharges derived from 92 gauging stations having not less than 10 years of records. A great deal of effort was put into preparation of the stream flow data, the main tasks comprising filling in gaps and extensions of records by correlation with records of one or more nearby gauging stations, using bivariate linear regression of the logarithms of the recorded flows. After manipulation of the records in this way had been completed, the array of data for the majority of stations extended over periods between 17 and 30 years, with a median value of 25 years.

The partial series model was selected for flood frequency analysis, and a threshold level of discharge corresponding with one event per year was adopted. The Poisson distribution was accepted as representing the probability that a peak flow exceeding the threshold level of discharge would occur, but it was found that a three-parameter distribution was required to represent the probability that a peak chosen from those exceeding the threshold level of discharge would also exeed a value of interest, and accordingly the log-Pearson type III (LP3) frequency distribution was adopted for this purpose.

Three fitting procedures were tested for estimating the parameters of the LP3 frequency distribution – viz:

- the method of moments applied directly to the flood events, designated as the method of moments (direct)
- the method of moments applied to the logarithms of the flood events, designated as the method of moments (indirect)
- the maximum likelihood procedure

The method of moments (indirect) appeared to fit the data well and was adopted accordingly.

Previous studies have used multiple linear regression of the logarithmic transforms of catchment characteristics for regional flood estimation, and the same approach was considered suitable for the purpose of this investigation. However, to ensure that meaningful results were obtained from such analyses, it was first necessary to ensure that the variables selected were not strongly correlated. As a result of a check made by means of a simple correlation matrix of catchment characteristics with probability of exceedance discharges, it was discovered that strong correlation existed between mainstream length and catchment area.

Although mainstream length was shown to be slightly more strongly correlated with probability of exceedance discharge than catchment area, it was decided that catchment area should be selected because mainstream length was not necessarily uniquely defined, and its determination was very sensitive to map scale.

Study of the correlation matrix also showed a lack of correlation between rainfall intensity and mean annual rainfall. This conclusion is not consistent with the results of similar studies made by others, but it was considered that the apparent anomaly may be a consequence of the large errors involved in extracting representative mean annual rainfall figures. It was considered that rainfall intensity would have a more significant effect on maximum instantaneous discharge than mean annual rainfall, and hence no further attention was direction to the latter parameter.

The selection of hydrologically homogeneous regions proved to be a very subjective process. Reference was made to the Australian Representative Basins Program, which was initiated by the Australian Water Resources Council in 1965 with the objective of choosing a number of small drainage basins throughout Australia which were considered to be climatologically and hydrologically representative of the regions from which they were sampled. However, before adopting the regions defined by the Representative Basins Program, an attempt was made to define regions on the basis of maximum instantaneous discharges by plotting logarithmic residuals from a $Q_{0.10}$/Area regression. Ultimately a combination of both approaches was used, which led to the adoption of three regions which are shown, together with plots of logarithmic residuals from the $Q_{0.10}$/Area regressions for each of the respective regions, in Figure 6.

Based on the results of the regression analyses for $Q_{0.10}$, regressions were performed for $Q_{0.50}$, $Q_{0.20}$, $Q_{0.05}$, $Q_{0.02}$, and $Q_{0.01}$, and the best fit equations related discharge to catchment area, rainfall intensity, and the number of stream junctions per unit catchment area. The regression equations apply to catchments having areas in the range 50km² to 1000km².

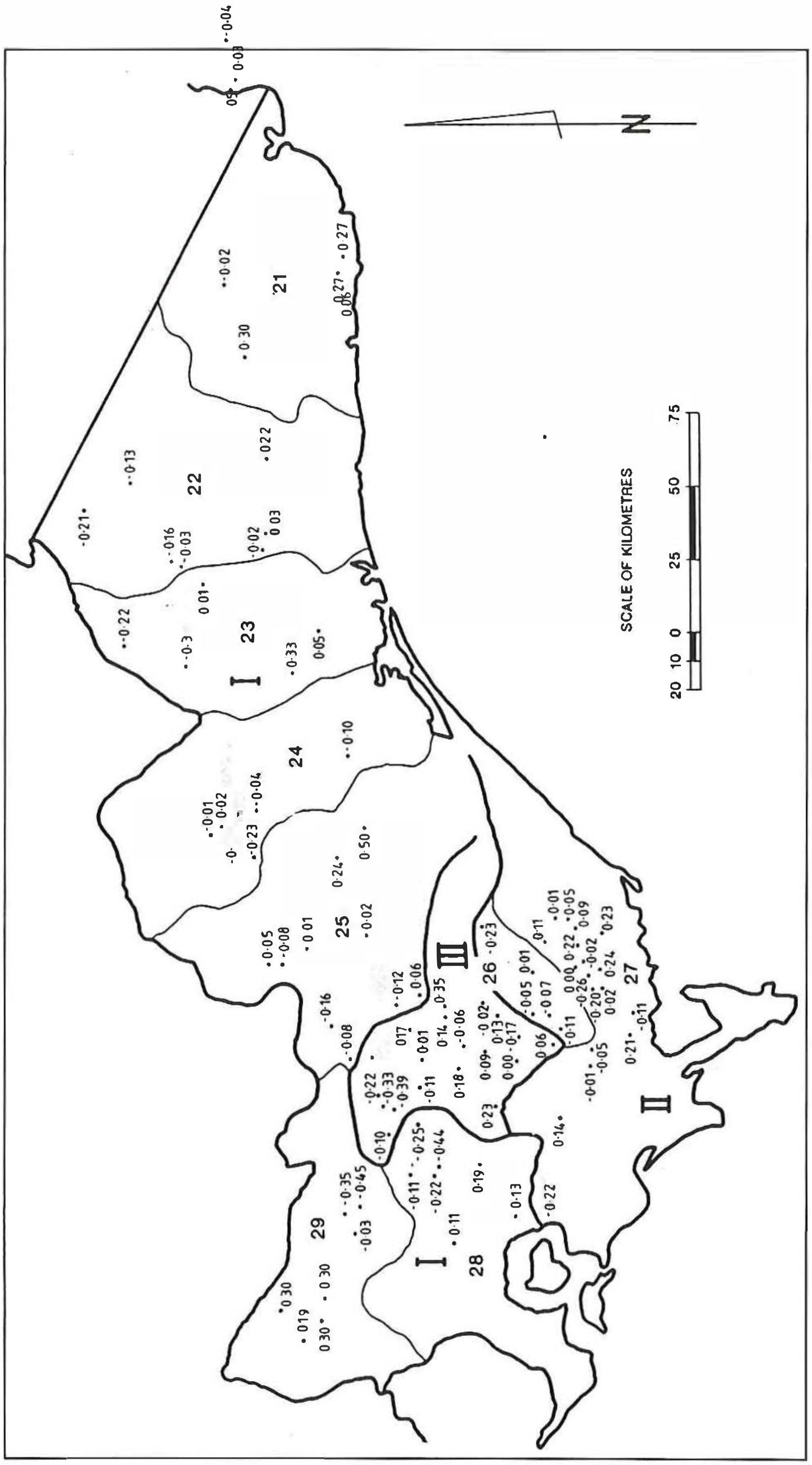


Figure 6
$Q_{0.10}$ logarithmic residual errors for final regional equations

Table 1

Region	No. of Sections	Best Fit Equations
I	48	$Q_{0.50} = 35.25\ A^{0.90}\ I_R^{1.11}$ $Q_{0.20} = 4.69\ A^{0.93}\ I_R^{1.06}$ $Q_{0.10} = 5.96\ A^{0.93}\ I_R^{1.05}$ $Q_{0.05} = 7.65\ A^{0.94}\ I_R^{1.03}$ $Q_{0.02} = 47.3\ A^{0.91}$ $Q_{0.01} = 58.9\ A^{0.98}$
II	23	$Q_{0.50} = 108\ A^{0.74}\ (J_T/A)^{0.97}$ $Q_{0.20} = 154\ A^{0.76}\ (J_T/A)^{0.96}$ $Q_{0.10} = 194\ A^{0.78}\ (J_T/A)^{1.00}$ $Q_{0.05} = 242\ A^{0.80}\ (J_T/A)^{1.04}$ $Q_{0.02} = 324\ A^{0.82}\ (J_T/A)^{1.12}$ $Q_{0.01} = 402\ A^{0.84}\ (J_T/A)^{1.18}$
III	19	$Q_{0.50} = 0.870\ A^{0.92}\ I_R^{1.78}$ $Q_{0.20} = 0.720\ A^{0.93}\ I_R^{2.12}$ $Q_{0.10} = 0.635\ A^{0.94}\ I_R^{2.34}$ $Q_{0.05} = 0.572\ A^{0.95}\ I_R^{2.55}$ $Q_{0.02} = 0.509\ A^{0.97}\ I_R^{2.98}$ $Q_{0.01} = 0.466\ A^{0.99}\ I_R^{2.98}$

NOTES:

Q = discharge – M l/day
A = catchment area – km²
I_R = rainfall intensity for 12 hour duration storm of 2 year return period – mm/hr
J_T/A = number of stream junctions per unit area – number/km²

A pilot study of the accuracy of the results obtained by application of the regression equations indicated median differences between the gauged catchment flood frequency estimates and the corresponding regression equation estimates of +25% and +40% for $Q_{0.10}$ and $Q_{0.01}$ discharges respectively.

In constrast to the regression equation approach, the commonly applied Rational Method requires subjective judgement in the determination of the runoff coefficient and time of concentration, and as a consequence, widely varying estimates of discharge are commonly made by different designers.

It was considered instructive, however, to compare Rational Method estimates with those of the regression equation approach. Rational Method median differences were +130% and +60% for $Q_{0.10}$ and $Q_{0.01}$ discharges respectively for the runoff coefficient and time of concentration parameters selected for the comparison. Even at gauged sites, $Q_{0.01}$ discharges are difficult to determine reliably because of the limited length of gauging station records and therefore the above $Q_{0.01}$ median differences should be viewed with some reservations. However, the $Q_{0.10}$ median differences give an indication of the improvement of the regression equation estimates over those of the Rational Method. The differences also indicate that the Rational Method greatly overestimated the discharges in the majority of cases.
It should be noted that methods of estimating flood discharges on ungauged rural catchments are generally considered to be successful if the error in the estimate is within ± 40%.

The most significant problems encountered during the course of the study concerned the inadequacy of existing methods for defining hydrologically homogeneous regions. The form of the regression equations and the associated values of coefficients are very sensitive to slight variations of regional boundaries, and the accuracy of estimates of flood flows clearly is similarly influenced.

However, work presently being done by the Division of Water and Land Resources of C.S.I.R.O. appears to be leading towards the concept of classification of landscapes in a hydrologic sense, and the possibility that catchments may be categorised rather than aggregated into regions. If that approach shows promise it will be given consideration in conjunction with the extension of this study, with the objective of further improving the accuracy of the estimates of flood discharge obtained by application of the new method.

Computer Applications in Bridge Design

A comprehensive computer program "BEAMAN" has been developed for use on the RCA's mainframe computer in conjunction with the analysis and design of bridges.

The program has been written in such a way as to simplify input requirements without any loss of flexibility within the program. Default options significantly reduce input data for most runs, and an editing routine thoroughly checks all input for inconsistencies before any major calculations proceed. The program reduces design time by relieving the designer of many tedious calculations and enables the structural behaviour of complex bridges to be more thoroughly investigated.

Continuous beams with any span configuration or arrangement of supports may be analysed and each construction stage of a multi-stage bridge can be analysed within one run. Most forms of construction can be handled by the program including:

- Prestressed concrete beams
- Post tensioned box girders
- Reinforced concrete structures
- Segmental construction
- Composite beams
- Steel beams

The following loading conditions can be analysed:

- Concentrated and distributed loads
- Settlement of supports
- Prestressing loads
- Differential Temperature effects
- Shrinkage and creep effects
- Effects of removal of temporary supports
- Truck and lane loads plus impact (automatic generation)
- Abnormal vehicle loads plus impact (automatic generation)
- User-defined moving axle loads

The program calculates values of the following parameters at specified locations for individual load cases or any prescribed combinations of them:

- Bending moment
- Shear force
- Axial force
- Deflection
- Bending and axial stresses
- Shear stresses
- Principal stresses
- Reactions and slopes at supports

and can assess ultimate bending moment and shear capacities of prestressed concrete members.

Plots of bending moments, shear forces, deflections and stresses can also be produced on the RCA's CALCOMP plotter.

The 'BEAMAN' program is extensively used in the Bridge Design Division, and since its initial development in 1979 has been used to assist in the design of over 80 projects, including extensive use in the design of the West Gate Freeway structures.

Sulphides in Metasedimentary Rocks

Certain metamorphic and sedimentary rock types which are quarried for aggregate and crushed rock production have been found to contain significant amounts of sulphide mineralisation (generally pyrite and marcasite, FeS2 at concentration of up to 0.3%). When quarried and exposed to the atmosphere, oxidation of the primary sulphides produces highly soluble sulphate compounds. During oxidation and recrystallisation of these new minerals, a volumetric growth occurs which may cleave the fissile rock.

When used as a crushed rock base, the soluble sulphates migrate in solution to the pavement surface if a free-evaporative surface is present. Damage to thin and relatively permeable asphalt overlays has occurred due to the recrystallisation and growth of the sulphate minerals at the base-course/asphalt interface. This damage has been observed, particularly on the outer edges of trafficked pavements, and generally on non-trafficked pavements (as shown in Fig. 7).

Physical damage to sprayed seal surfaces has not been observed although rust-staining of surfaces has been reported. These pose an aesthetic problem only and have not materially affected the performance of the surfacing.

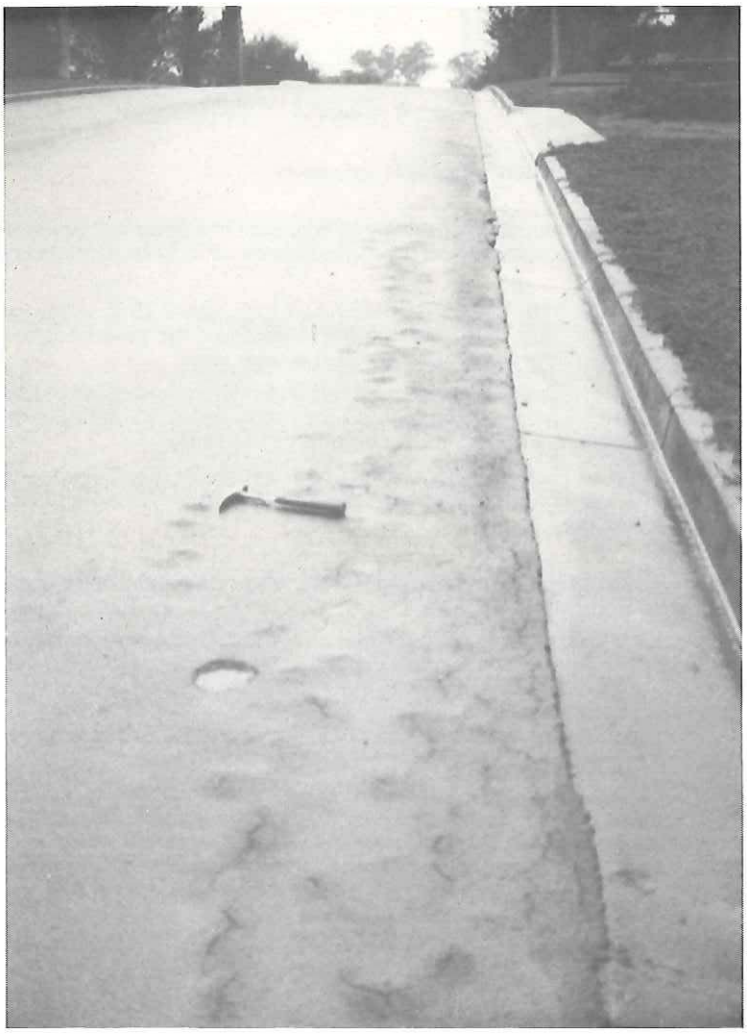


Figure 7
Sulphide affected pavement

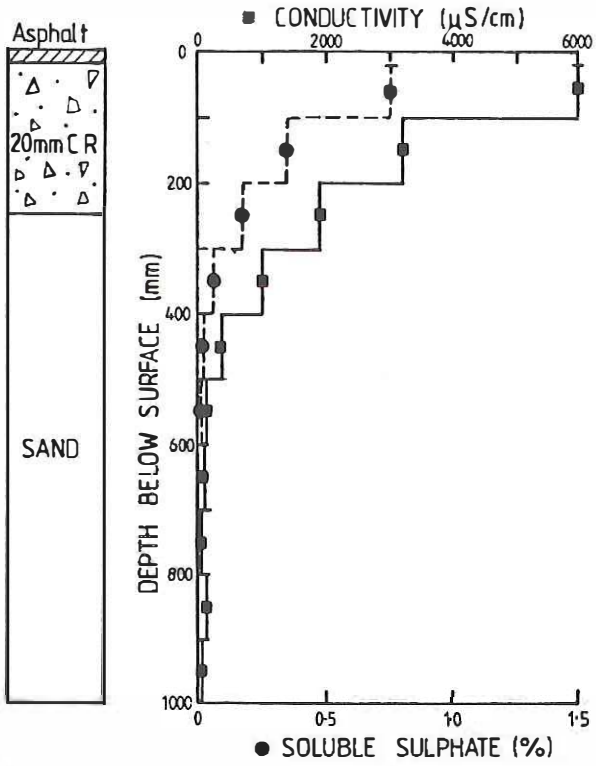


Figure 8
Relative concentration of soluble sulphates

Fig. 8 shows the relative concentration of soluble salts present in a pavement profile constructed from sulphate-bearing basecourse, where the asphalt surface has been damaged by sulphate salts.

The original concentration of sulphate in the crushed rock was 0.29%. After construction of the pavement, the salts migrated from the lower levels of the pavement to produce a concentration of 0.75% in the upper 100mm of the base layer.

Laboratory investigations have shown that the addition of calcium hydroxide or lime, (applied as LIMIL) to the crushed rock base material effectively reduces the solubility of the sulphate minerals present thus preventing upward migration of the salts.

The addition of lime to sulphate-bearing crushed rock pavement material should provide a solution which will allow continued use of these materials where it is planned to overlay with thin asphalt surfacing.

The Quality of Basalt Determined from Percussion Drill Hole Chips

When examining proposed basalt quarry sites, or when determining the reserves of good quality rock in existing quarry reserves, it is often not possible, due to economic constraints, to obtain an adequate coverage of the deposit using diamond coring techniques. It is common practice, however, to obtain chip samples of rock using the less expensive and less time-consuming percussion drilling technique. A method has been used which allows comparisons to be made of the properties of the percussion chip samples with the properties of materials sampled either from existing quarry faces or from diamond cores.

Total surface-area (TSA) determinations are carried out on powdered samples derived from different depths in a percussion drill hole. These determinations provide a relative estimate of the amount of clay present in the rock sampled. The clay content of the samples gives an indication of the amount of mineralogical alteration or weathering that the source rock has been subjected to in the geological past and thus provides an indication of the durability of the rock when used in pavement construction.

Data derived from research carried out on many basaltic rock sources in Victoria suggests that materials with TSA values in excess of 60 m^2/g (approx) are of marginal durability and those with values in excess of 100 m^2/g would be considered unsuitable for the use as a road construction material.

Fig. 9 compares the TSA values obtained for samples derived from both diamond core samples and percussion chip samples which were obtained from separate but adjacent bores.

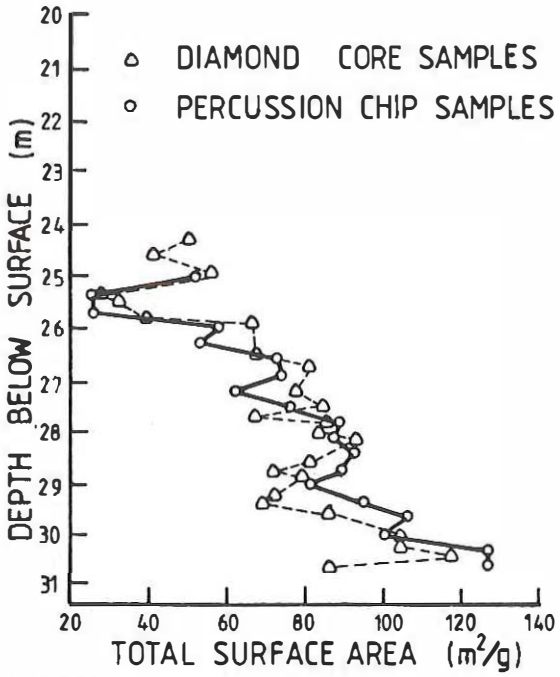


Figure 9
Total surface Area Values for sample obtained by both methods

Assessment of High Strength Reinforcing Bar

A new edition of AS 1302-Steel Reinforcing Bars for Concrete, was issued in 1982. This edition included a new higher strength grade of bar, 410Y. This grade is designed to have a high minimum yield stress of 410 MPa and restricted amounts of alloying elements. These two features are used to reduce the quantity of steel required in reinforced concrete components and to allow easier welding during manufacture of cages and placement of reinforcement.

Subsequently, two local steel manufacturers have introduced to the market two different reinforcing bars which are supplied to the requirements of AS 1302-410Y. The grade is basically a high-strength, low-alloy steel, and the two bars achieve the requirements of the grade by different metallurgical techniques: heat treatment, and micro-alloying.

The heat treatment method uses feed steel made through the smelting, casting and rolling techniques of a fully integrated steelworks. Finally the hot rolled deformed bar is partially quenched and self-tempered at the immediate end of the rolling sequence. The finished bar has a distinct, fine-grained microstructure which varies with radius.

The micro-alloying method remelts and refines selected scrap steel, making molten steel to which micro-alloying additions are made prior to the continuous casting of rolling mill feed billets. The billets are reheated and hot rolled into deformed bar. The final air-cooling creates a uniform, fine-grained microstructure throughout the bar.

An assessment of each of the two bar types has been carried out to establish compliance with AS 1302-410Y for material properties and also to determine the response of the bars to welding under various conditions.

(i) **Materials Property Assessment**

Both types of bar were tested for chemistry, tensile properties and bending behaviour.

The micro-alloyed bar has suitable chemistry, with low carbon, medium to high manganese and significant vanadium contents. There is a small amount of residual element pickup from the raw scrap steel.

The heat treated bar has a different chemistry with carbon close to the allowed maximum and low to medium manganese. Contributions due to other residual elements are very small. The carbon equivalent value for this steel is also controlled to not exceed the allowed maximum value.

Yield stress and tensile strength properties measured on the samples of the two bar types were satisfactory and similar. Elongation and 180° bending tests provided results that demonstrated excellent plastic deformation behaviour of the grade 410Y bar.

(ii) **Welding Response**

Samples of both types of bar were welded to test weld response to flash butt welding and manual metal arc welding, including tack welding.

Flash butt welding is a common method for extending the length of bars. Considerable heat is required which does influence and alter the microstructure of the bar adjacent to the joint. All joints tested had acceptable yield stress and tensile stress, and all bend test samples passed the same criteria as for the as-supplied bar.

Two types of tack welds were made on the bars, a small cross tack weld simulating a reinforcing cage joint and a longitudinal tack weld 50mm long simulating a lap welded splice. The majority of tests proved satisfactory with the occasional failure at a weld site due only to weld crater cracks.

This investigation has shown that reinforcing bar can be supplied to satisfy the requirements of AS 1302-410Y, by using metallurgically different steels. Such bars can be welded satisfactorily by different techniques and simple welding procedures, without detrimental effects, due to the low carbon equivalent values for the steels.

A Field Evaluation of Nuclear Gauge Calibration Methods

Nuclear density/moisture gauges are calibrated to enable estimates of wet density and moisture content to be made from the measured nuclear count ratios. The calibration of these gauges is a contentious subject with a variety of calibration procedures being used by testing authorities.

The RCA has been involved with the National Association of Testing Authorities in a field evaluation of the various methods of calibrating nuclear gauges. Wet densities, moisture contents and dry densities of a layer of crushed rock pavement were determined by four gauges at 40 sites using the manufacturer's Blocks calibration. Subsequently the corresponding orthodox test values were measured by the Sand Replacement (SR) and IPCAD tests.

It was concluded that the manufacturer's calibration based on solid blocks of metals and stones can result in substantially biased estimates of orthodox wet densities, moisture contents and dry densities. When gauges are calibrated against orthodox test values, the so-called Field method of calibration, biases can also occur due to the limited number of sites on which the calibration is based and also operator bias in the orthodox tests. Biases can also occur in the Blocks-Field calibration method, where the manufacturer's Blocks calibration is offset using the results of orthodox tests. The evidence of the study tended to suggest that potential bias in the Field method of calibration was less than the biases which can occur using the Blocks or Blocks-Field methods.

It was also noted that the IPCAD wet and dry densities were on average 2.2 % above the values determined in the SR test. The data suggests there is a genuine difference in the results of the two orthodox test methods.

New Developments in Laboratory Equipment

Two new pieces of laboratory equipment have recently been developed to improve the test procedures used in laboratories.

A motorised mechanical soil compactor has been designed and constructed to carry out compaction of moulds for moisture/density and Californian Bearing Ration (CBR) testing to Australian Standard AS 1289.

The machine consists of a freely falling rammer made from a rectangular hollow steel section into which interchangeable feet may be inserted. The compaction mould is placed on a circular table which is arranged to rotate during the lifting stroke on the rammer. By controlling the angle of rotation a slight overlap of the impressions occurs between two successive rammer blows.

A novel feature of the machine is the means used for lifting the rammer. Two rubber coated friction rollers, one of which is power driven and one of which incorporates a rotary pulse generator, are arranged to grip the rammer through a spring and an electric solenoid actuating mechanism. On the lifting stroke the rammer is lifted to the desired height above the compacted surface of the mould then released and allowed to fall freely under gravity. This allows exact replication of the hand compaction test. A maximum speed of 60 blows per minute is achieved.

The design of the hammer was instigated to provide a simple, reliable means of carrying out compaction with a minimum of wearing parts. The elimination of the usual mechanical chain and rack and pawl lifting mechanism in current commercial designs has greatly reduced maintenance. Another feature is the ability to readily scale up the design to operate larger compaction hammers and moulds than those currently in use.

A soil grating machine has been developed which achieves a rapid break up of soil for compaction/density determinations. This task, usually performed over a 19mm screen by hand sieving and pounding with a mallet, is generally a time-consuming and arduous process.

The machine comprises a power driven circular disc 600mm diameter rotating at 50 revs/min. The disc is made from expanded metal of the type usually used for walkway grid mesh. The sharp edge of the deformed section produces an ideal cutting surface to the soil sample which is placed on the disc and pressed onto the disc with an inclined flat plate. The shredded soil falls through the disc into a tray.

Samples produced are of thin shredded section ideal for subsequent control of moisture by air drying or water addition. The process is particularly suited for wet sticky clay and enables sample preparation in a fraction of the time of the conventional hand process.

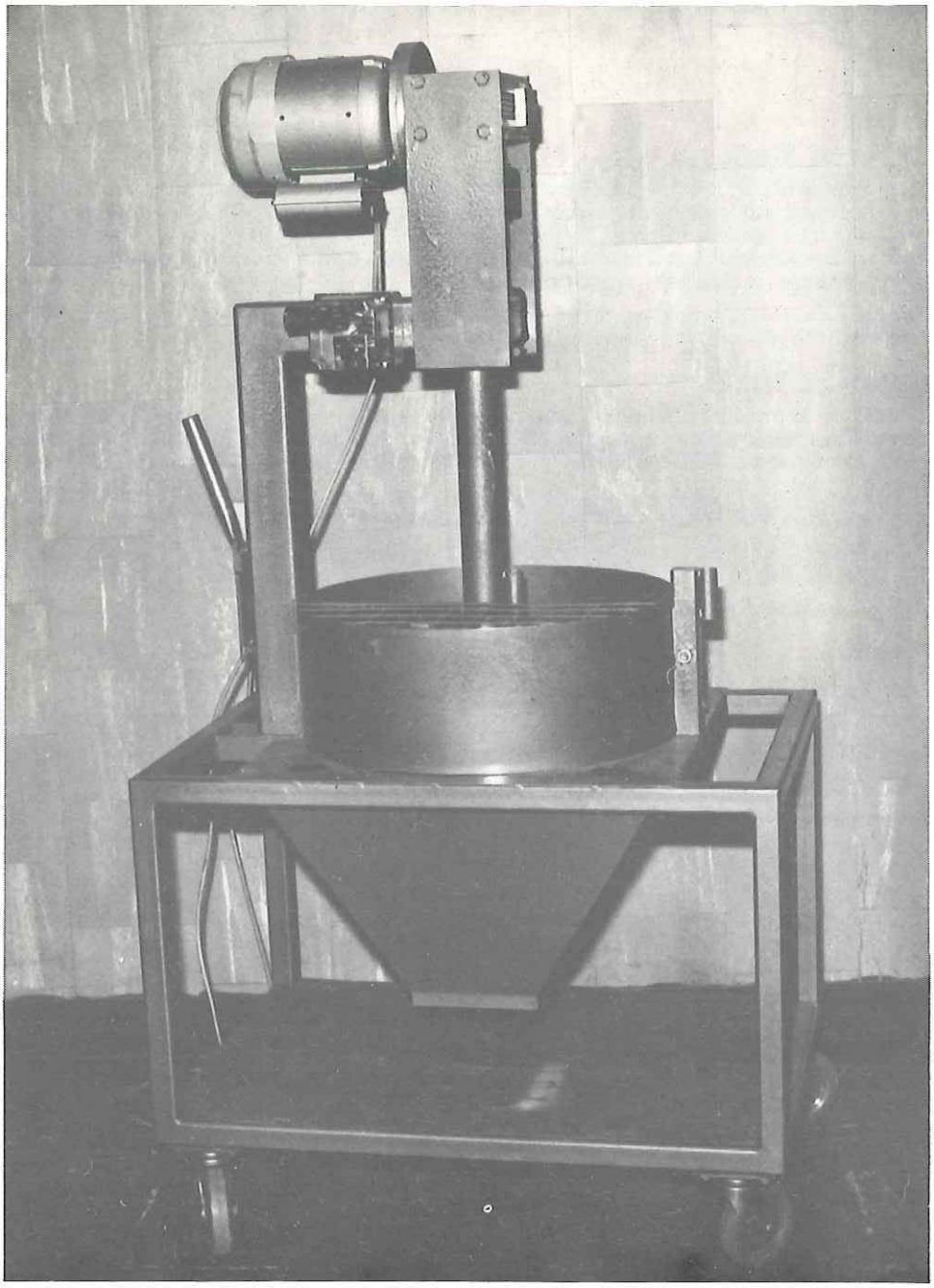


Figure 10
The soil grating machine

Bituminous Surfacing

Types of Work

Approximately 96.1% of the total length of bituminous surfacing carried out in 1983-84 was of the sprayed seal type. This process involves the spraying of a thin hot bituminous layer on to the road surface, followed by spreading a layer of aggregate which is rolled into the bitumen by pneumatic tyred rollers and controlled traffic. It is an economical surfacing process which provides a safe, skid resistant surface.

The balance of bituminous surfacing work was of asphalt surfacing which is plant mixed and spread in a layer with a mechanical paver.

Extent of Work

The RCA's 16 mobile bituminous surfacing units, together with plant owned by municipal councils and contractors, completed 4867 km of sprayed work at a cost of $42 million on roads to which the RCA contributes plus 309 km of sprayed work for other authorities.

Contractors operating from fixed asphalt plants completed 199 km of plant mix work at a cost of approximately $21.3 million using 378,500 tonnes of asphalt.

The following table shows the total extent of bituminous surfacing work carried out during the year together with a comparison with that done in 1982/83.

Table 2

Bituminous Surfacing work completed

Category of road and plant used	1982/83 km		1983/84 km	
Work on roads to which the RCA contributed funds:				
RCA declared roads				
RCA's plant	2330		2455	
Municipal plant	92		154	
Contractor's plant	242		349	
	2664		2958	
Unclassified roads				
RCA's plant	1523		1558	
Municipal plant	207		332	
Contractor's plant	195		218	
Sub-totals	**1925**		**2108**	
		4589		5066
Work done for other Authorities by the RCA's plant				
No RCA contributions for these works)				
Municipalities	368		308	
State Instrumentalities	4		1	
Commonwealth works	1		–	
		372		309
Totals		**4961**		**5375**

The following table shows the extent of bituminous surfacing work on various road categories to which the RCA contributed funds during 1983/84. Restoration of seal coats on reconstructed pavements amounted to 402 km of the declared road system, 1.8 per cent of the sealed length compared with 1.6 per cent in 1982/83. Retreatment on declared roads amounted to 1899 km, 8.5 per cent of the sealed length, compared with 1833 km, 8.4 per cent in 1982/83.

Table 3
Bituminous surfacing work on various road categories (on roads to which the Authority contributed funds during 1983/84)

Type of Work	State H'ways	F'ways	Tourists' and Forest Roads	Main Road	Total RCA's Declared System	Unclassified Roads	Totals
Initial treatments							
Extensions to sealed system							
Sprayed work	15.3	10.16	28.04	15.59	69.09	382.53	451.62
Plant mix work	–	2.79	–	–	2.79	2.77	5.56
Reconstruction of lengths of previously sealed pavements							
Sprayed work	112.30	26.88	8.30	223.05	370.53	255.17	625.70
Plant mix work	14.09	.26	–	17.23	31.58	33.65	65.23
Widening of exiting sealed pavements							
Sprayed work	47.85	11.40	2.80	45.43	107.48	72.39	179.87
Plant mix work	5.85	–	–	5.60	11.45	1.96	13.41
Duplication of existing sealed pavements							
Sprayed work	13.44	8.60	–	.28	22.32	.58	22.90
Plant mix work	6.30	–	–	9.90	16.20	–	16.20
Final seal							
Sprayed work	184.63	33.44	32.14	151.08	390.29	253.05	643.34
Plant mix work	5.44	3.17	–	13.53	22.14	7.10	29.24
Ancillaries to other major works							
Sprayed work	1.26	7.54	.73	.48	10.01	.45	10.46
Plant mix work	1.49	2.92	.30	.04	4.75	.27	5.02
Retreatment							
Sprayed work	706.18	64.98	88.02	996.50	1,855.68	1,077.44	2,933.12
Plant mix work	21.23	7.87	.90	13.46	43.46	20.99	64.45
Totals	1,135.36	180.01	150.23	1,492.17	2,957.77	2,108.35	5,066.12

Cost of Work

The average unit costs for sprayed work done by the RCA's 16 bituminous surfacing units are shown in the following table.

Table 4
Average costs of sprayed bituminous surfacing done by RCA plant (on roads to which the Authority contributed funds during 1983/84) (Costs in cents per m²)

	Nature of Work										
Item	ITP&S Size 14 & Over	ITP&S Size 10	ITP&S ITP&S Size 7	2 Appln Seal	IT Primerseal	ITSO & ITFS & Reseal Size 14 & over	ITSO & ITFS & Reseal Size 10	ITSO & ITFS & Reseal Size 7	ITSO & ITFS & Reseal Size 5	BSRS Reseal Size 14	BSRS Reseal Size 10	Surface Enrichment
Squares metres costed	578,127	797,753	32,895	7,751	2,679,595	5,135,825	8,765,028	6,794,911	601,657	545,473	245,136	203,040
Material Cents	113.1 59.2	115.2 65.0	90.9 64.0	177.2 64.8	79.8 62.4	95.8 61.8	77.7 62.3	63.1 62.2	60.4 63.7	113.0 58.7	107.9 54.9	28.1 70.6
Stores Cents	7.5 3.9	5.8 3.3	4.9 3.4	9.5 3.5	4.3 3.4	5.6 3.6	4.4 3.5	3.7 3.6	2.8 2.9	8.7 4.5	8.1 4.1	1.0 2.5
Plant Cents	29.4 15.4	22.6 12.8	19.2 13.5	43.0 15.7	18.9 14.8	21.9 14.1	16.7 13.4	13.9 13.7	13.8 14.5	26.7 13.9	30.4 15.4	4.3 10.8
Labour Cents	41.1 21.5	33.5 18.9	27.2 19.1	43.6 16.0	24.8 19.4	31.7 20.5	26.0 20.8	20.8 20.5	18.0 18.9	44.2 22.9	50.4 25.6	6.4 16.1
Totals Cents	191.1 100	177.1 100	142.2 100	273.3 100	127.8 100	155.0 100	124.8 100	101.5 100	95.0 100	192.6 100	196.8 100	39.8 100

ITP&S indicates "Initial Treatment Prime & Seal" ITSO indicates "Initial Treatment Seal Only"
BSRS indicates "Bitumen Scrap Rubber Seal" ITFS indicates "Initial Treatment Final Seal"

The average overall cost of all types of sprayed work was $1.29 per square metre compared with $1.22 in 1982/83, an increase of 5.7 per cent.

The average cost per tonne for asphalt supplied and placed was approximately $55.17 per tonne in the Melbourne and Geelong areas, and approximately $67.61 per tonne in other areas of the State. The overall average cost per tonne was $56.50, compared with $52.09 in 1982/83.

Materials

(a) **Aggregate**

The total quantities of aggregate used were approximately 281,000 cubic metres for sprayed work undertaken by the RCA, 61,000 cubic metres for sprayed work undertaken by municipalities and contractors and 257,000 cubic metres for asphalt.

The following table shows the average prices in roadside stacks of aggregates for sprayed work over the last five years.

Table 5

Material Prices/cubic metre	79/80	80/81	81/82	82/83	83/84
	$	$	$	$	$
Screenings	15.73	17.83	19.59	22.16	23.98
Gravel	14.72	16.92	17.29	22.20	23.27
Sand	8.95	8.86	9.37	14.01	13.47
Scoria	8.55	9.70	13.48	14.90	17.77
Average price all aggregate	15.43	17.54	19.27	22.06	23.79

(b) **Bitumen**

The RCA purchased 37,500 tonnes of bitumen by contract with four suppliers at a cost of $10,620,000.

Treatment of an Environmentally Sensitive Site – Maroondah Highway

In the past the Maroondah Highway at "The Hermitage", 80 km from Melbourne, was known by regular road users for its tight reverse curve and a number of huge trees which closely abutted the road. Many accidents occurred at this location and large trucks and buses could not traverse the curve without encroaching into the opposite traffic lane.

This location is also well known for, and takes its name from, a nearby historical building named "The Hermitage" which was built in the 1890's and used as a guest house. The surrounding forest contains many species of the natural flora, including tree fern and ground fern, which make the area an attractive stopping place for tourists.

Improvements to the curve were achieved by deviating the highway through crown land and "The Hermitage" property which is freehold land. The Department of Conservation, Forests and Lands consented to the use of the crown land for transport purposes. The Historic Buildings Preservation Council and National Trust of Australia (Victoria), both of which have an interest in the preservation of "The Hermitage" and its surrounds, were also consulted. The Healesville Shire Council agreed with the proposed deviation and the regional planning authority, the Upper Yarra Valley and Dandenong Ranges Authority, was consulted during both design and preconstruction planning.

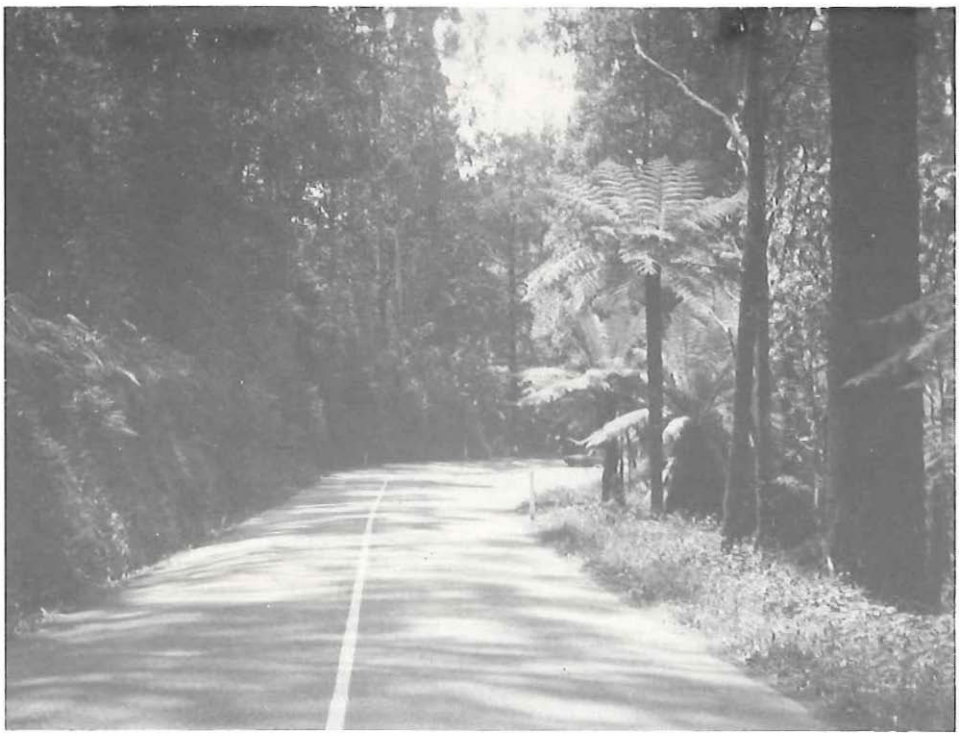


Figure 11
The approach to "The Hermitage" curve from Melbourne prior to roadworks

Because the area is environmentally sensitive, a number of measures were taken to protect and reinstate it. The measures included strict control over clearing limits, construction of crib retaining walls adjacent to large trees, storage and re-planting of natural vegetation, propagation from cuttings of some species, and re-use of topsoil and mulch containing the spore and seed of naturally occurring plant species.

Roadworks included filling a very deep fern gully with 18,000 cubic metres of fill over a longitudinal distance of only 80 metres. Construction work was very difficult within a confined area at the bottom of the gully, the only access being a steep and narrow track. The deviation was completed in July 1984 at a cost of $350,000.

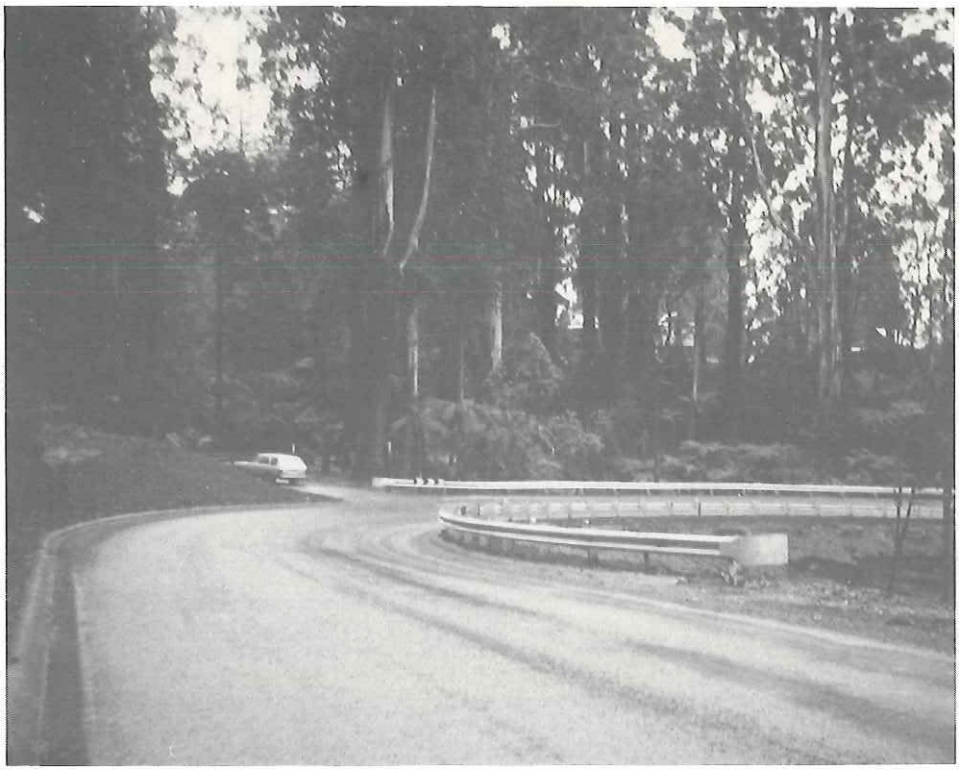


Figure 12
The same location after completion of roadworks

Transplanting of Mature Trees – Western Highway

Twenty-five mature English Elm trees in the Ballarat Avenue of Honour were transplanted in May 1984. This was to enable intersection improvement works to be carried out at the intersection of the Western Highway and Ring Road, Ballarat.

The trees had an average trunk diameter of 300mm and heights varying from 6 metres to 9 metres, and were set back approximately 12 metres to allow for the necessary road widening and intersection treatment works.

The operation proceeded as follows:

(i) **Root preparation**

The root preparation consisted of hand excavating a 2 metre radius, 600mm wide trench around the tree and to a depth dependent on the roots, usually to a depth of 900mm. Fertiliser was then sprinkled on the tree side of the trench, covered with polythene and backfilled. All roots were clean cut with secateurs.

To reduce shock to the trees half the circumference of the trench was excavated in April 1983 and the other half in October 1983.

(ii) **Transplanting**

Holes at the new tree locations were dug and the surface of the bottom of the holes shaped to receive the transplanted tree.

The trench around each tree was re-excavated and widened to allow for working room. The soil and roots at the bottom of the trench were undercut. The root ball was then bagged, tied to the tree trunk by a special collar and chain arrangement, and lifted by chains through the tree branches by a 60 tonne crane to the new position. Refer to figure 12. After some "fitting" of the tree to the bottom of the new hole, the hole was then backfilled around the transplanted root bowl.

The total operation to relocate the trees took 8 days.

(iii) **Follow Up**

Each tree was well watered after being moved to its new location.

When the trees had been settled into their new location each tree was given a light pruning to remove all dead wood and reduce top growth for the first growing season.

Following another good watering two weeks after transplanting it is expected that all trees will re-establish in the new locations without assistance.

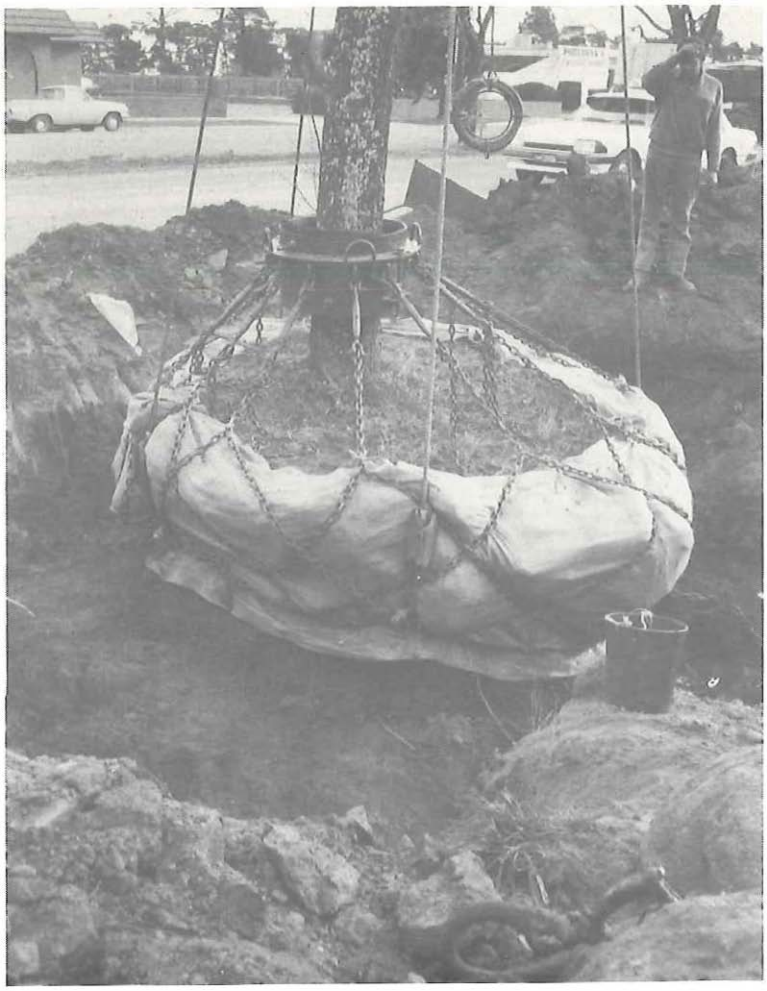


Figure 13
Tree being lifted clear of the old location. The root ball has been bagged and is contained by a collar and chain arrangement

The work was carried out under contract by Establishment Tree Transplanters Pty Ltd assisted by RCA direct labour personnel. The total cost of the work was $50,000.

Traffic Detour – Maltby Bypass, Princes Freeway West

Traffic was detoured during the period 25th June 1984 to 24th July 1984 on the Maltby Bypass by using one carriageway of the freeway to operate two way, while the MMBW's West Truck Sewer was constructed under the opposite carriageway. This section of the freeway is subject to fogs in winter and carries high speed traffic.

The Maltby Bypass carries approximately 16,000 vehicles per day on a normal week day with higher volumes on holidays and weekends and speed studies showed that the 85th percentile speed was 109 km/hr.

The freeway has two sealed carriageways each 7.4 m wide divided by a median 12 m wide between seal edges.

A number of alternatives including a detour through Werribee Township were investigated to cater for traffic during the estimated four week construction period and the one considered most appropriate involved the construction of two side tracks on the freeway (one for each of the two stages of the sewer crossing construction).

Cross over points on the median were selected after considering road drainage and level differences between the two carriageways.

After the side track design was established, a signing and line marking scheme was prepared, based on the "Roadworks Signing Code of Practice". This layout was supplemented with large advance direction signs and longer approach tapers.

Use was made of trailer mounted electronic sequential flashing arrow signs while setting up the permanent tapers and to supplement the fixed signs during peak periods. Use was also

made of reflectorised raised rubber flaps as lane dividers through the two way traffic area and adhesive removable white lines were used on the tapers. Both the lane dividers and adhesive white lines were reused on the second stage detour.

Advice of the impending detour was given to all relevant authorities, eg. Ambulance, Police, bus operators, etc and also the overdimensional permits section of the RTA. Overdimensional width vehicles were prohibited or permitted only under escort and police supervision. Advance publicity signs advising motorists of the detour were also erected on site a few weeks before the detour commenced.

No speed limit was imposed for the detour and observed average traffic speed was 80 km/h. Traffic used this detour during both stages without noticeable time loss and without incident.

Impact Attenuator

The construction of the Victorian Arts Centre Complex has included decking for a plaza over parts of City Road and Sturt Street, South Melbourne. The location of the columns supporting the plaza required Sturt Street to be realigned and the use of New Jersey barriers to shield the columns and to deflect errant vehicles. Sturt Street will be used as an access road to the West Gate Freeway for west-bound traffic from east of St Kilda Road.

It was evident that the column in the gore area between City Road and Sturt Street represented a potential hazard to road users and it was therefore decided to install an impact attenuator in front of this column and to extend New Jersey type barrier walls back from it to enclose additional columns and a concrete staircase leading to the Plaza.

As there were no commercially made impact attenuators available in Australia it was necessary to investigate attenuators available overseas.

The attenuator recommended was manufactured by Energy Absorption Systems Incorporated of West Sacramento, California, U.S.A. and marketed under the name of Guard Rail Energy Absorbing Terminal (G.R.E.A.T.).

The G.R.E.A.T. system impact attenuator was chosen for this location because :

(a) it was cheaper than other suitable systems available;

(b) The size is compact in width and not excessively long, and would therefore present the least target to an out-of-control vehicle causing a lesser incidence of hits than might have been expected; and would make it less visually obtrusive;

(c) routine maintenance cost was anticipated to be virtually nil;

(d) full scale crash tests in the U.S.A. have shown this system to perform well within deceleration criteria.

The expected range of decelerations experienced by a motor car in a head on collision at this location using a four bay (plus nose) impact attenuator is considered to be acceptable.

Figure 14
G.R.E.A.T. Impact attenuator in place in South Melbourne

During a head-on collision the G.R.E.A.T. unit telescopes as the energy of the impact is absorbed and dissipated by the cartridges which contain dry multiple lightweight vermiculite/concrete cells. The side panels are fastened together through slotted holes that slide alongside one another in a telescopic manner. The whole unit is attached to anchor bolts in the concrete base by means of chains, which slip off the open end leg pins when hit head-on to allow telescoping but restrain the side panels. When hit from the side, no parts fly loose to cause possible secondary accidents. When a vehicle hits the unit at a side angle, the vehicle is redirected into the flow of traffic at a much more shallow angle than that at which it hit giving the driver a chance to regain control of the vehicle.

The cost to deliver the unit to site was $17,000. The impact attenuator, the first of its kind to be installed in Victoria, took five days and cost $4,000 to install including the concrete base and backing block.

Naasra Roads Study – Some Victorian Results

The NAASRA Roads Study (NRS) was commenced in late 1980 and completed in early 1984. The objectives were to:

(a) provide a clear picture in measurable terms of the nature and condition of the Australian road system;

(b) provide a basis (along with earlier surveys and continuing surveys) for assessing changes in (and the rate of change of) the nature and condition of the Australian road system;

(c) provide a basis for assessing the effects of alternatives for the management of the road system;

(d) illustrate the physical effects on the Australian road system, and in the cost of transport on it, of various levels of funding;

(e) present the findings in a manner that can be readily communicated to and understood by all.

Rural arterial, urban arterial and local roads were studied separately.

Study Method and Procedures

The approach taken in this study centred on an examination of the implications of various future funding levels. A limited number of future funding levels was defined, relative to the funding in 1980/81, and related to projected future funding by the various levels of government. For each of the funding levels, the future (1991) physical effects on the network and travel costs were estimated in terms of changes to the base year (1981) network, and between funding levels.

For each of the road categories a funding level defined as set out below, and denoted F100, was adopted:

F100 Total funds available for expenditure on a road category over the analysis period (end of June 1981 to end of June 1991) if the 1980/81 expenditure on that category were to be continued in constant values over the period.

Other levels were defined in terms of proportions of this level, e.g. F75 is 75% of F100.

Rural Arterial Roads

Two significant features of the assessment of rural arterial roads were:

(a) development of quality of service criteria; and

(b) use of a computer simulation model to estimate the effect on the road network and the travel on it of various funding levels.

Various measures were used for describing the existing and future road conditions. Two criteria, for each of the measures, were defined for the purpose of assessing the length of road, and corresponding travel on this length, giving qualities of service which can be described as poor, fair or good.

The tasks of formulating project sets, for each funding level, and estimating future network effects were undertaken using NIMPAC. (NAASRA Improved Model for Project Assessment and Costing) This is a model which simulates the processes of pavement deterioration, traffic growth, road improvement on an individual road section basis, and provides a summary of these individual simulations at an overall network level. The model was developed by NAASRA prior to the commencement of the study, although it was tested and further developed as an integral part of the study.

The model was used to estimate 1991 road network conditions for given values of the assessment and design standards (and certain other input parameters) and the expenditure required to achieve these standards. The standards and parameters were then adjusted to give expenditures approximating the funding levels to be evaluated, and the resulting 1991 conditions were reported. The model also calculated vehicle operating, travel time and accident costs for both 1981 and 1991.

Urban Arterial Roads

Traffic service measures were also a major aspect of the study of urban arterial roads. They were derived from three largely separate forms of analysis based on road inventories, traffic

Table 6
NAASRA Roads Study : Summary of Main Quantitative Results – Victoria

FACTOR[1]	RURAL ARTERIAL ROADS						URBAN ARTERIAL ROADS[2][10]				LOCAL ROADS		
	National Highways			Other Rural Arterial							Urban		Rural
ROAD STEREOTYPES % of Length (% Travel)	Unsealed	Sealed	Divided	Unsealed	Sealed	Divided	Two Lane	Other Undivided	Divided	Freeways	Unsealed	Kerbed	Sealed
1981	0	73	27 (49)	2	97	1.2 (12)	29 (14)	45 (45)	21 (30)	5 (11)	20	64	24
1991 • F50	–	–	– –	–	–	– –	29 (15)	45 (41)	21 (31)	5 (13)	–	–	–
• F75	0	60	40 (70)	2	97	1.4 (16)	–	–	–	–	18	70	25
• F100	0	56	44 (74)	1	97	1.9 (20)	26 (13)	43 (38)	26 (36)	5 (13)	15	76	27
• F125	0	50	50 (79)	1	97	2.4 (24)	25 (12)	43 (38)	27 (38)	5 (14)	11	83	29
• F150	0	48	52 (81)	1	96	3.4 (29)	25 (12)	42 (34)	28 (39)	5 (15)	–	–	–
QUALITY OF SERVICE	Poor[4] Traffic Service (% Trav.)	Very Rough (% Lgth)[5]	Bridges too Narrow (%)[6]	Poor[4] Traffic Service (% Trav.)	Very Rough (% Lgth)[5]	Bridges too Narrow (%)[6]	Poor Mid-block Service[7] (% Travel)	Poor Intersection Service (% Throughput)	Peak Speed Under 40 km/h (% Travel)		Very Rough (% Lgth)[5][8]	Poor[4][8] Traffic Service[6] (% Lgth)	Low Strength Bridges (%)[8][9]
1981	5	0	2	17	1	5	27	35	57		4	1	26
1991 • F50	–	–	–	–	–	–	49	61	70		–	–	–
• F75	12	not	0	21	14	2	–	–	–		not	0	19
• F100	8	calculated	0	16	11	2	46	55	65		calculated	0	17
• F125	3		0	12	10	2	44	53	62		–	0	15
• F150	2		0	7	10	2	42	50	58		–	–	–

- The main function of local roads is to serve adjacent residents and occupiers.
- The quality of service depends on the road standard.
- The standard is related to stereotype as:
  - unsealed roads cause dust and health problems
  - sealed urban roads without kerb are often in very poor condition
  - natural surface and ungravelled roads are periodically put out of commission by wet weather, requiring a major access restoration effort.

TRAVEL COSTS AND ECONOMIC RETURN	Unit Travel Cost: Cents/veh km	Unit Travel Cost: % Change	Benefit/Cost Ratio: Funding Increment: Range	Unit Travel Cost: Cents/veh km	Unit Travel Cost: % Change	Benefit/Cost Ratio: Funding Increment: Range
1981	28.2	base		21.7	base	
1991 • F50	–			23.3	(+7%)	
• F75	29.2	(+3.8%)	F75 to F100 : 2.0 to 4.2	–		F50 to F100 : 4 to 9
• F100	28.7	(+2.0%)	F100 to F125 : 1.2 to 2.4	22.4	(+3%)	
• F125	28.4	(+0.9%)	F125 to F150 : 0.7 to 1.4	22.1	(+2%)	F100 to F150 : 2 to 3
• F150	28.2	(+0.3%)		21.7	nil	

- Expenditure on local roads will provide some travel cost savings, but these were not quantified in this study.
- Previous studies have shown that only part of local roads expenditure is justified by economic return alone.
- Provision of local roads can be viewed as a basic community service, such as education and health. With this view equity considerations are more relevant than economic return.

ACCIDENTS AND FUEL	Funding Increment	Accidents (per year in 1991) Fatal	Accidents (per year in 1991) Injury	Fuel (%) (million litres per year in 1991)	Funding Increment	Accidents (per year in 1991) Fatal	Accidents (per year in 1991) Injury	Fuel (%) (million litres per year in 1991)
Reduction for defined Funding increments	F75 to F100	13	87	30 (1%)	F50 to F100	9	240	60 (2%)
	F100 to F125	10	70	24 (1%)	F100 to F150	5	200	30 (1%)
	F125 to F150	9	61	10 (–)				

- Additional funding for local roads would make a small contribution to savings in accidents and fuel.

(1) F100, the base funding level, is a continuation of 1981 funding in real values from 1981 to 1991. F125 is a 25% increase over F100
(2) Values for F125 derived by interpolation between F100 and F150
(3) Full freeway or divided arterial with a high degree of access control
(4) Traffic volume too high for the road stereotype
(5) More than 139 counts per kilometre, NAASRA Roughness Meter (NRM), sealed roads only
(6) Bridges too narrow for the traffic volume
(7) Peak volume/capacity ratio greater than 0.9
(8) Rural local roads only
(9) Less than half the legal load capacity
(10) All cities in the MSD plus Shire of Diamond Valley

assignments (undertaken using urban transport planning techniques) and other surveys and analyses.

Two criteria were adopted for each of the traffic service measures, for the purpose of assessing the extent of the network giving levels of peak traffic service which can be described as poor, only fair or good.

Local Roads

For local roads a two stage study was undertaken. In the first stage use was made of available data, similarly defined for and common to all LGAs, to provide an overall description of local roads in relation to LGAs, and for use as a data base in developing sampling procedures for the second stage. The second stage comprised the sampling of a number of LGAs (22 out of a Victorian total of 211) and local roads within them (approximately 1000 road sections in Victoria). The sampling and subsequent analysis was undertaken separately for four LGA groupings – urban, urban/rural, rural, and sparse rural – defined mainly on the basis of population density.

Summary of Victorian Results

Table 6 summarises the main results for Victoria. Further information is available in an RCA brochure "Victorian Aspects of the NAASRA Roads Study, 1984", a 180 page RCA "Report on the Victorian Road Network" and various national NAASRA roads Study publications.

Melbourne Travel Time Surveys

During late 1983, a travel time survey of Melbourne inner urban arterial roads was undertaken. The primary purpose of the survey was to provide data for the urban arterial component of the NAASRA Roads Study but the results will also provide a basis for future performance monitoring of the Melbourne urban arterial road network.

The results of the surveys give a broad indication of the performance of the arterial road network on an area basis and assist in the definition of major traffic problems. In addition, the surveys provide a basis of determining the accuracy of simulated future speed estimates based on traffic assignments. These assignment based speeds formed part of the assessment criteria for future funding levels in Melbourne.

The road length surveyed comprised 422 km of primary arterial roads which represented 54% of the total primary arterial road length and 24% of the length of all arterial roads in the study area.

In analysing travel time data on an area basis, consideration needs to be taken of different amounts of travel on the various links surveyed. A greater weighting needs to be given to a slow speed link carrying a high traffic volume than a slow speed link carring little traffic. Similarly the different length of links surveyed needs to be considered in the analysis procedure.

The calculated AM and PM mean speeds together with the distribution of link speed by daily travel are shown in Table 7.

Table 7

MEAN SPEED AND TRAVEL DISTRIBUTION (PEAK PERIOD)
MELBOURNE – 1983

Area	Mean Travel Speed weighted by AADT				% of Travel on Roads with Speed					
					under 20 km/h		20 to 40 km/h		over 40 km/h	
	AM		PM		AM	PM	AM	PM	AM	PM
Central	24	(±2)*	30	(±2)*	26	12	42	54	32	34
Inner	32	(±2)	33	(±2)*	7	5	47	45	46	50
Middle	40	(±2)	40	(±1)	4	4	33	43	63	53
Outer	51	(±1)	46	(±2)	0	3	17	23	83	74
Study Area	39	(±2)	38	(±1)	7	5	35	41	59	54

* 95% Confidence limits based on variation between days

The figures show that an increase in speed with increasing distance from the central area is accompanied by substantial reductions in the proportion of travel distance covered at speeds of less than 20 km/h and between 20 km/h and 40 km/h. While only a small proportion of the network length operates at very low speeds it carries a much greater proportion of network travel.

Road Roughness Measurement

Between November 1981 and April 1982 a survey was undertaken on 15,900 km of sealed rural arterial roads using the standard NAASRA Roughness Meter as part of the NAASRA Roads Study.

These roughness measurements include the effects of both surface irregularities (due to seal breaks or patches) and deformation in the underlying pavement. They provide a partial measurement of those aspects of overall structural roadway condition which do not directly relate to defects such as transverse deformation (e.g. wheel rutting), cracking and drainage deficiencies, and structural pavement weakness. In that roughness provides a good indication of ridability it is a measure of quality of service to the road user.

The distribution of roughness by road length shown in Figure 15 was obtained by averaging values over sections of approximately two kilometres in length. Particular ranges of the unit of measurement (counts per kilometre) were denoted poor, fair and good to aid description and interpretation.

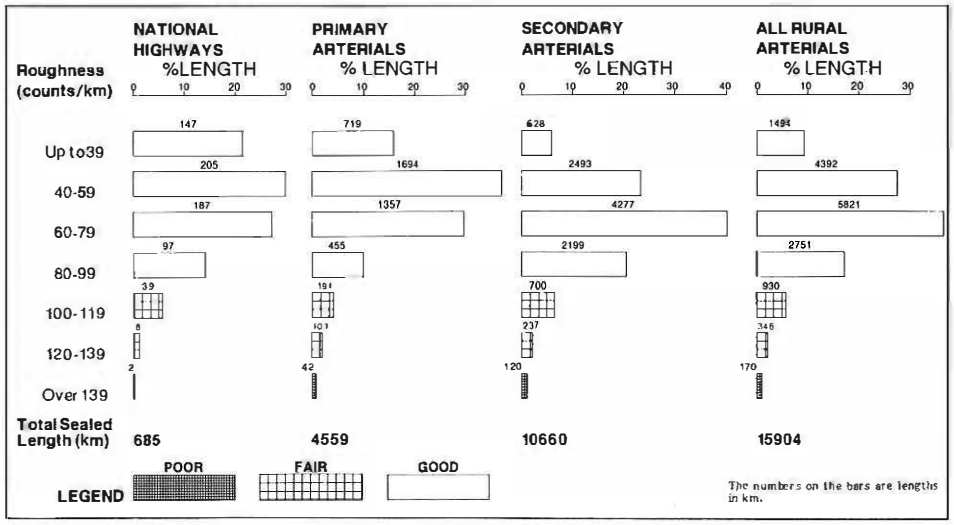


Figure 15
Roughness of sealed roads – 1981

On national highways and primary arterials the typical roughness is about 50 counts per km. This reflected the effect of current maintenance, re-surfacing and rehabilitation practices, which were expected to continue into the future.

For secondary arterials the typical roughness is about 70 counts per km. A higher roughness is tolerated on the secondary arterials because of their lower traffic volumes and their lesser function importance.

Assessments of Road Network Performance for Metropolitan Sub-Regions

In order to assess the performance of any part of the road network a comprehensive "inventory" of existing road and traffic conditions is needed. A great deal of inventory data does exist from specific project investigations and some routine data gathering. This is usually recorded and held by a variety of units and is not readily available as useful information to perform assessments.

In a three year program, to supplement particular project investigations, a comprehensive inventory of the arterial road system has been produced for that part of the metropolitan area which is west of the line formed by Hoddle Street and High Street.

The inventory consists of the following types of information –

- location of significant barriers to travel and major traffic generators:
- description of the road network identifying the important continuous routes, the various classifications of the road network and the current road improvement works being carried out by the various highway authorities. This description includes information about the Road Cross Sections and Intersection Controls
- estimates of 24 hour traffic volumes, peak hour traffic characteristics and truck volumes in sufficient detail to permit peak period performance of potentially critical intersections to be analysed.

- the analysis of intersection degrees of saturation from the above data, together with other network information, permits overall assessment of the present performance of the road network. This is assessed firstly in terms of capacity/congestion highlighted by overloaded intersections, secondly it is assessed by lack of connectivity in the road network where barriers interrupt the continuity of various arterials, and thirdly performance is assessed by poor amenity identified by having high traffic volumes and large numbers of trucks on 20 metre or narrower roads, particularly through residential and shopping areas.

This inventory has provided excellent background to several issues that have had to be investigated or commented on as well as a useful data base of major road studies.

ABS: 1981 Census and Journey to Work Data

Australian Bureau of Statistics data relating to Persons and Dwellings and Journeys to Work from both the 1981 and 1976 censuses are available. Although the actual levels of aggregation vary with the census year and the type of data, the following are generally available; collector district (CD), transport (MTC) zones and local government areas (LGA's).

Journey to Work Data

The journey to work data provides tabulations of trips between each origin (either a CD or LGA level) destination (MTC zone level) pair classified by descriptors such as method of travel, industry, occupation, number of vehicles, sex and income.

The statistical package SPSS is used to access the data and allows cross tabulations to be produced between many of the descriptors although with descriptors on the different files not all cross tabulations can be produced. Tables can be produced for both the 1976 and 1981 data with the latter year data being available at levels of aggregation finer than LGA Level.

In the past year the journey to work data has been used for the METRAS study and to report on the 'Journey to Work – 1981 Census : within the MSP and surrounding Shires'. This report provides tables and figures which summarises work travel behaviour in the Melbourne Statistical District and a comparison with a similar summary prepared from the 1976 Census gives an indication of changes that have occurred. The journey to work data is currently being used to produce updated models of the demand for travel.

Person and Dwelling Data

The person and dwelling data records for each geographic area contain about 30 data items identifying and describing the geographic area in 34 summary tables. The summary tables provide many descriptions of the population of the area – marital status, duration of residence, family type, education, income to name but a few. Other summary tables provide descriptors of the dwelling of the area – structure, occupants, rooms etc.

Computer programs have been developed to enable the summary tables required for road planning studies to be easily extracted and combined to produce total values for a study area. These programs can now produce information for the 1966, 1971, 1976 and 1981 censuses.

Determination of Permissible Gross Mass for Low Loaders

For many years, the determination of a permissible gross mass for low loaders has been both a difficult and time-consuming task for those involved in the issue of permits. The basic reason behind this difficulty is the very wide range of axle configurations possible with a low loader. The typical low loader comprising a prime mover, a dolly and a low-bed trailer can vary in the following ways:

- Number of axles used, e.g. from 5 to 9 axles;
- Number of wheels per axle, e.g. either 4 or 8 wheels per axle;
- Spacing between each axle can vary independently;
- Distribution of load on each axle or axle group can vary;
- Width of the dolly and trailer can vary independently usually over a range from 2.5m to 4.3m.

Thus, any specific low loader can vary in any one of the above ways or a combination of some or all of them.

The limiting factor for determining permissible gross mass is the load capacity of the existing bridge system. Assuming 25% overstress and a 10% impact factor (implying low vehicle speed), maximum allowable live-load bending moments are calculated for a range of bridge spans (simply supported and continuous) up to 45 metres. Shear forces are also considered but bending moments have been found to be generally more critical. Gross mass is then limited to that which will not produce live-load bending moments exceeding the maximum allowable values.

Using past experience, a list of 14 different low loader axle configurations, representing the types most commonly used, was drawn up. The permissible gross mass for each type of low loader was determined for a range of vehicle widths from 2.5 to 4.3 metres. The axle loads and axle group loads adopted for this determination are those contained in the recently published NAASRA Study of the Road Movement of Indivisible Items – Task Group Report No. 1 (1981).

Figure 16
A 4.3 m wide low loader and CAT 641 Scraper at the Seymour weighbridge

It is expected that this method of gross mass determination:

(a) may produce slightly different results than the present method because of the lack of uniformity within the present system.

(b) should greatly assist officers involved with the issue of permits and reduce the need for referring many permit applications to bridge engineers for investigation.

Design

COGO

The most significant road design computer program introduced within the past year was 'COGO;. The program was obtained from the Main Roads Department, Queensland, and enhanced by the RCA. The program can be used by road designers to design and store 3-dimensional models of complex interchanges and intersections, such as roundabouts and to produce plans of these.

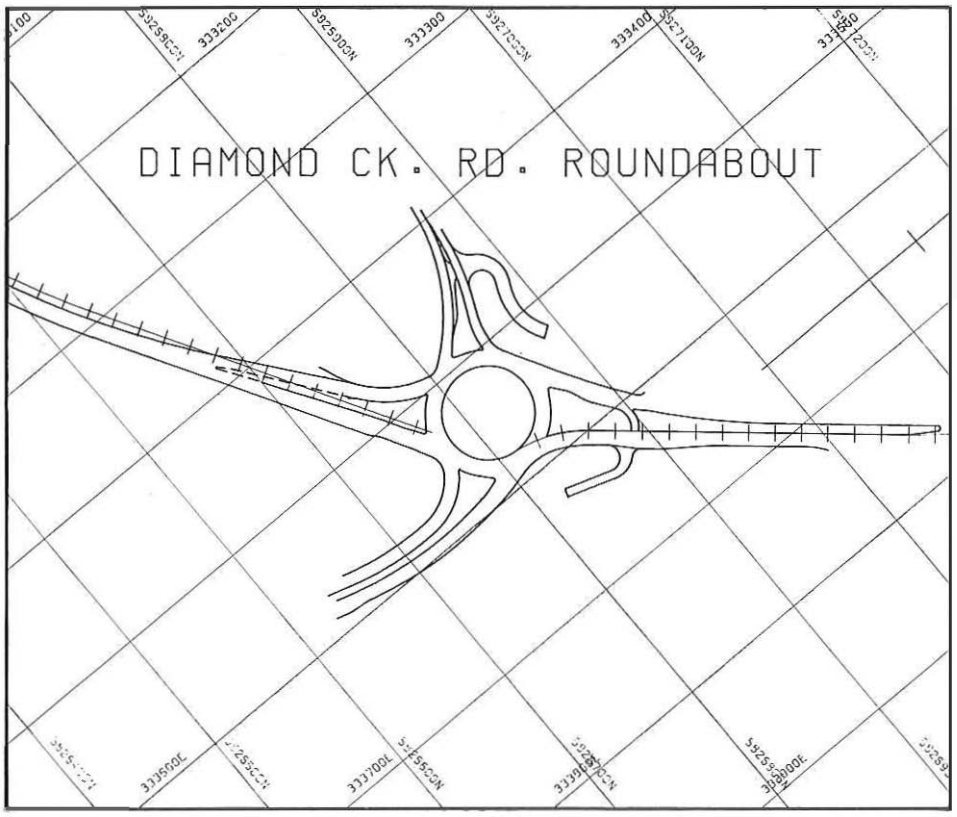


Figure 17
COGO example – Roundabout design

COGO output can also be fed into the other road design computer systems to produce contour plans and cross sections.

COGO is currently available to road designers on the RCA mainframe computer, and is being modified to run on microcomputers located in the design offices.

Another computer program developed within the RCA allows for the transfer of survey or design data to/from other authorities, consultants, etc. The transfer is performed via magnetic tape with information written on tape according to Australian Standard AS2482 (Interchange of Feature Coded Digital Mapping Data).

During the past year a comprehensive set of video tapes were produced for the education of road design staff in the use of all Road Design Computer Systems.

Analytical Stereoplotters

The RCA has now in operation two Wild Aviolyt BC1 analytical stereoplotters, augmenting the Wild A10 analogue stereoplotter already in service.

Figure 18
Information interchange example

The mapping capabilities of the three units are at present being used on the plotting of large scale base maps for the Bicentennial Roads Roads Program.

The Wild A10 analogue stereoplotter solves the central-perspective relationships between the photograph image and the stereo model by mechanical means, compared to the Aviolyt BC1 analytical stereoplotter where this function is realised digitally in a process computer.

The Aviolyt BC1 stereoplotter:

(i) operates by interactive dialogue with the operator, relieving the operator of numerous repetitious tasks and draws attention to errors by automated functions. In the Aviolyt BC1, photographs of any focal length and inclination can be plotted. All data entered, including the data for model orientation, remain stored in the computer even when the instrument is switched off. In conjunction with the Aviotab TA2 Digital Plotting Table and supplied plotting software, the Aviolyt BC1 can plot a map at any enlargement ratio from photograph to map. The comprehensive software package provides computer assistance at every stage. The system automatically plots control points and grids, symbols and labelled spot heights, draws straight lines between any two points, plots parallel, curved or straight lines, completes rectangular plan shapes, shades an enclosed area and can annotate the plot.

(ii) is particularly suited to numerical data acquisition and processing. Numerous different forms of registration and processing are available. The data is recorded on disk as the mass storage medium and if required a plot can be provided on the plotting table simultaneously with registration of the data points.

(iii) is capable of dealing with a large variety of measuring tasks in terrestrial and close range photogrammetry. There are no restrictions on the focal length of the cameras lens system, any picture format can be accommodated, and restitution of inclined and moderately convergent photographs is possible.

The use of the Aviolyt BC1 stereoplotter in pavement analysis work, materials evaluation, bridge inspections, roadside furniture assessment and monitoring of road and bridge works are all to be investigated.

The Aviolyt BC1 stereoplotter offers a high order of accuracy, flexibility and economy in all fields of application and is proving to be a highly versatile precision instrument.

Metropolitan Direction Signing

A program of improved route direction signing has been commenced in the Melbourne metropolitan area.

The program provides for signing of approximately 225 major intersections over the next few years at an estimated cost of $850,000. Direction signs will be placed in advance of or beyond each intersection to provide motorists with the following information:

(i) the names of intersecting roads (shown on the signs in a white panel);

(ii) selected suburb names as destinations along intersecting roads;

(iii) the name of the route being travelled and distances to suburb destinations along the route ahead.

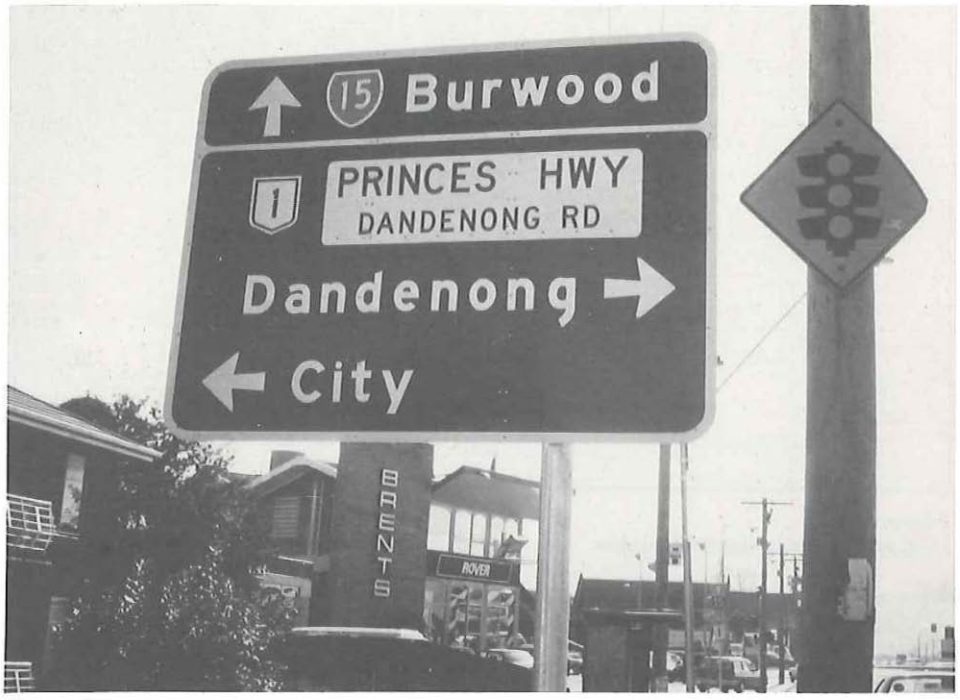


Figure 19
Sign on single post support on Warrigal Road at the southern approach to Princes Highway East

The signs will be fully reflectorised, that is, both the legend and the sign background are reflectorised using a recently introduced class 1 grade material. The use of this new material enhances both the legibility and conspicuity of the signs at night.

The choice of suburb destination to be shown on the signs has been the subject of discussion and agreement between the RCA and the metropolitan councils with whom there is close liaison in respect to the design and location of the new signs.

During the implementation of this program the opportunity is being taken to upgrade and extend the existing metropolitan route numbering system.

Innovative approaches have been taken in both the design of the sign faces, in which computer aided design and drafting techniques have been developed and used extensively, and in the design of sign support structures to suit often difficult site conditions and achieve an effective and generally sensitive aesthetic treatment.

Computer Aided Design of Road Signs

As a result of a substantial increase in the number of direction sign drawings required to be produced in fully drafted form, the RCA has developed a series of Computer Aided Drafting (CAD) programs for the preparation of drawings of standardised forms of direction signs. The requirement has arisen from the need to have large numbers of such signs manufactured by commercial suppliers, either by quotation or contract, to meet requirements of National Highways and ABRD Project administration, and the recently commenced Metropolitan Direction Signing Scheme. The CAD facility will also aid production of signs in the RCA's own sign workshop.

The programs have been written in a combination of "Macro Basic" and "GDS (General Drafting System)" languages to run on the RCA's Tektronix 4114A terminal linked via a 9600 baud

rate Telecom line to a commercially operated Prime 250 Computer. The programs are of the order of 2000 lines long.

The feature of this system is that it will produce drawings of standardised sign layouts very quickly i.e. approximately 10 minutes per sign including keying in of data and processing time, but excluding program search and entry. This reduces the time normally taken to prepare a sign drawing by about 75%. Data entry is by a menu of prompts on a VDU and can be made by relatively inexperienced operators.

Programs have been developed to cover approximately 75% of the requirements for standard direction signs. An example computer output of a Metropolitan Direction Signing Scheme sign is shown in figure 20.

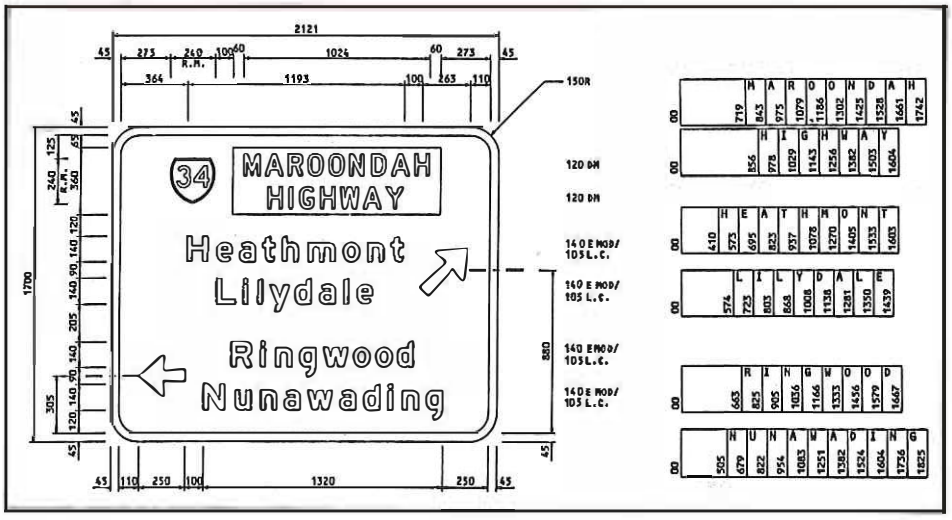


Figure 20
Computer output for ADS type 61-V4A single sign assembly

Survey

Total Station

The term "Total Station" describes a survey instrument which integrates the functions of a conventional theodolite and an electronic distancer (Refer Fig. 21). The horizontal and vertical circles of the theodolite are replaced by electronic encoders which enable direction and elevation values to be displayed and/or stored electronically, together with distance values, in an attached storage device. Point descriptions and other data may be entered into the device by keyboard.

Figure 21
A "Total Station"

The storage device has search and edit functions. The information held is capable of direct transfer to a computer. Several operations previously manually performed are replaced by automatic operations resulting in direct and rapid data gathering, editing and computer entry, reducing operator fatigue and error and producing a better product in a shorter time.

A unit has been tested over the last year, mainly in the gathering of ground feature information. This information is then used in the SPUR/RIDGE computer based survey and design system.

West Gate Freeway Project Control Survey Towers

The West Gate Freeway Project involves the construction of an elevated carriageway structure some 2km in length. This structure consists of concrete segments weighing up to 90 tonnes,

which are to be manufactured and placed to higher precision than is normally associated with this type of work.

To achieve this precision, special high-accuracy survey equipment including theodolites, electronic distance measurers, optical plummets and precise levels, has been obtained for the dimensional control of the manufacture of the segments in the casting yard and their erection on site.

Because of restricted visibility on the project and the need for direct observation to the deck of the structure from survey instruments, four elevated survey control stations have been built at regular intervals throughout the site. (Refer Fig 22). Each station consists of two independently founded and separate towers. The inner tower carries an instrument platform located above the co-ordinated survey mark. The outer tower provides access to the observing platform 10 to 12 metres above ground level. Three stations are built on piled foundations and the fourth is located on one of the few basalt outcrops on the project. The outer towers are clad with galvanised steel sheeting and isolate the instrument platform from the effects of weather and operator induced vibration.

The actual survey mark is carried on the top of a 1.5 metre high pillar and survey instruments may be used at ground level utilising openings in the covering of the outer tower. A high precision optical plummet is used to centre the instruments exactly over the mark in the pillar below when the elevated station is used.

The four elevated stations together with marks placed on surrounding substantial buildings form a stable network for primary survey control of the project. The first determination of survey control using these stations and the high accuracy survey equipment has indicated that the precision predicted by computer simulation methods of about 5mm has been obtained despite some problems with vibration of the inner tower due to nearby traffic.

Figure 22
Control survey tower at the elevated section of the West Gate Freeway in South Melbourne

General

Safe Working Practices

The RCA requires that the safety of personnel and the public be regarded as prerequisite of all of its road construction and maintenance activities.

The development of safe working practices initially rests with a six member Safe Working Practices Committee which is responsible for developing procedures, practices, guidelines, instructions and codes to ensure the protection of employees and the general public.

Twenty-two Regional Safety Committees work at an operational level to assist in workface implementation of safe working practices, the solving of local safety issues and surveillance of accident and personal injuries.

A Safety Conference, attended by representatives from all regional committees, is held at regular intervals to consider and communicate proposals for improvements to safe working practices.

The dissemination of safety information to RCA personnel is provided through regular training courses and workshops or by:

(i) the issue of circulars, to cover broad issues or to introduce a code or instruction;

(ii) the issue of codes of practice to detail specific practice for important topics;

Table 8
Causing Injury

Case of Injury	Total Number 1979/80	1980/81	1981/82	1982/83	1983/84
1. Arising out of or use of plant/vehicle/ machinery	393	373	335	259	103
2. Exposure to or contact with harmful substances, e.g. Epoxy	56	40	19	32	33
3. Using powered or other hand tools/equipment, e.g. chain saws	372	390	401	233	136
4. Falling, knocking, slipping, jumping, etc.	369	360	348	302	423
5. While manual handling	422	323	327	385	430
6. Arising out of a housekeeping problem	47	24	34	31	30
7. Working environment/ weather, e.g. allergies, sunburn	61	78	87	66	82
8. Electrical discharge	2	2	4	4	5
9. Other (including insects, misadventure)	104	156	102	132	95
10. Journey or recess accidents	Incl. in 1	43	85	122	112
11. Repetition Strain Injuries **					43
Totals	1,826	1,792	1,742	1,566	1,572
Note: Four categories (1, 3, 4 and 5) account for over these quarters of the accidents.	*85%	81%	81%	75%	75%

* Possibly high as it includes journey or recess accidents.
** Included in Categories 1 to 10 prior to 1983/84.

(iii) the issue of pocket sized instructions that explain workface safety matters, e.g. hand mowing, chainsaws etc.

During the year the issuing of protective clothing was given a high priority to reduce the incidence of personal injury accidents. Protective clothing available for personal issue included safety footwear, high visibility clothing for both day and night, hearing protection devices, eye protection glasses, breathing apparatus, safety helmets and many ancillary items.

A safety campaign was mounted in November on the theme of an "Accident Free November". November was chosen because of the formerly high recorded incidence of accidents in that month. The campaign included inspection of worksites and protective clothing and also encouraged implementation of new initiatives.

A new interim code of "Roadworks Signing" was introduced during 1983 to provide a consistent approach to signing of roadworks. The code introduced many improved or new signs to provide the motorist with clear information about roadworks and to advise the motorist of road conditions and hazards.

Accident Statistics

All accidents involving injury to RCA personnel require the injured person to submit a Work Injury Report. From the information submitted it is ascertained whether the report accident is statistically significant and requires further investigation. A statistical accident is a work injury in which the person is absent for at least one day after the day of the accident. The accident statistics for the 1983/84 year and a comparison with statistics in recent years are given in Tables 8,9 and 10.

$$\text{Duration Rate (DR)} = \frac{\text{Days Lost}}{\text{Statistical Accidents}}$$

Video Films - Training of Experimental Officers

Video films have been produced to train laboratory staff on modifications to test methods and on the interpretation of test methods. The films are an ideal training medium and help ensure that technicians follow uniform techniques and procedures.

A training film on Plasticity Index Testing has been used in training sessions with staff from the Soils Classification Laboratory to identify common malpractices and show the procedures to be followed when working to recently introduced revised test methods.

Table 9
Part of Body Affected by Injury Accident

Part of Body	Total Number 1979/80	1980/81	1981/82	1982/83	1983/84
1. Head or neck	138	152	150	151	161
2. Limbs (includes wrists and ankles)	508	524	505	448	449
3. Spine	336	352	341	296	329
4. Eyes	231	191	163	140	139
5. Hands or fingers	372	363	317	327	254
6. Feet or toes	113	68	101	66	70
7. Cardiovascular	8	2	7	3	2
8. Skin/burns	17	20	29	20	14
9. Hernia	8	7	14	9	10
10. Loss of hearing	1	5	9	5	28*
11. Respiratory	8	20	4	8	6
12. Chest, stomach or shoulders	Not Known	-	142	129	104
13. Other	156	229	106	108	61
14. Fatalities	Nil	3	1	3	1
Totals	1,896	1,936	1,889	1,714	1,628
Injuries to the limbs, spine and hands account for nearly two thirds of the accidents.	64%	64%	62%	63%	63%

* Includes applications to Workers Compensation Board for a lump sum payment for partial hearing loss.

Table 10
Safety Statistics

Year	Statistical Accidents	Non-Statistical Accidents	Total Statistical and Non-Statistical	Total Manhours Worked (million)	Disabling Injury Frequency Rate (DIFR)	Duration Rate (DR)
1979/80	538	1,288	1,826	8.995	59.8	
1980/81	491	1,301	1,792	8.833	55.6	
1981/82	447	1,308	1,755	8.323	53.7	
1982/83	429	1,137	1,566	8.501	50.5	21.2
1983/84	**417**	**1,155**	1,572	**8.682**	**48.0**	**24.1**

Another film which was produced in conjunction with staff from the Department of Employment and Industrial Relations Trainer Training Centre Melbourne, documents the correct operation of the crushing equipment used to produce crushed rock from quarry spalls. This film pays particular attention to the safety practices which have to be followed in the Stone Crushing Laboratory.

A film has also been produced showing how possible new sources of material for road construction are located and evaluated. The film covers such topics as the geologist's preliminary investigation and how material is sampled with a backhoe for testing.

Publications

The following papers by officers in the Operations, and Planning and Design Branches of the Authority were presented or published in the 1983/84 year:

"Preliminary Studies for Estimation of Flood Discharge for Ungauged Rural Catchments in Victoria"
C A Adams, Engineer, and T A McMahon, Professor of Agricultural Engineering, University of Melbourne.
Presented at the NAASRA Bridge Engineering Committee 1983 Seminar on Waterway Analysis and Design, Adelaide, November 1983.

"Bridge Waterways – Hydrology and Design"
B Addis, Assistant Chief Bridge Engineer.
Presented at the NAASRA Bridge Engineering Committee 1983 Seminar on Waterway Analysis and Design, Adelaide, November 1983.

"Coastal Sand Dunes. An Engineer's View".
P F B Alsop, Engineer.
Presented at 56th Annual Conference. Royal Australian Institutes of Parks and Recreation. La Trobe University, Bundoora, December 1983.

"Hydraulic design of Koonung Creek Underground Conduit"
R Atkins, Senior Design Engineer.
Presented at the NAASRA Bridge Engineering Committee 1983
Seminar on Waterway Analysis and Design, Adelaide, November 1983.

"Dynamic Testing of Piles Socketed into Weak Rock"
P J Balfe, Geotechnical Sub-Group Manager, Materials Division.
Presented at the 4th Australia-New Zealand Conference on Geomechanics, Perth, May 1984.

"Dynamic Testing of Piles:"
P J Balfe, Geotechnical Group Leader, Materials Division.
Presented to a joint meeting of the Geomechanics Society and the Institution of Engineers, Australia, July 1983.

"NAASRA Roads Study: Technical Report T-1 : Funding and Expenditure"
G.J. Both Acting Advance Planning Engineer, and M.F. Cullinan, Study Team Leader.
Published December 1983.

"NAASRA Roads Study: Technical Report T-2 : Road Travel"
A.D. Boyd, Transport Economist, and M.F. Cullinan, Study Team Leader.
Published April 1984.

"Practical Perspectives – Road Planning"
G.J. Both, Acting Advance Planning Engineer.
Presented at NERDDC Workshop on Priorities for Research in Truck Fuel Conservation, Vermont [Vic], November 1983

"The Use of One Dimensional Models in Analysis of Natural Stream Flows"
G K Boully, Engineer.
Presented at the NAASRA Bridge Engineering Committee 1983 Seminar on Waterway Analysis and Design, Adelaide, November 1983.

"NAASRA Roads Study : Technical Report T-10: Road Travel Time and Speed Measurement"
A.D. Boyd, Transport Economist.
Published April 1984.

"Steam Curing of High Strength Concrete"
S B Bromham, Scientific Officer, and D Meadley, Experimental Officer, Materials Division.
Presented at I.E.A. (Institute of Engineers, Australia) Symposium on Concrete, Perth, October, 1983.

"NAASRA Roads Study: Rural Arterial Roads Report"
J.E. Cleeland, Study Team Engineer, and G.J. Both, Acting Advance Planning Engineer.
Published February 1984.

"NAASRA Roads Study: Technical Report T-7: Use of NIMPAC"
J.E. Cleeland, Study Team Engineer, and G.J. Both, Acting Advance Planning Engineer.
Published April 1984.

"NAASRA Roads Study: Technical Report T-9: Preparation and Use of Urban Arterial Road Inventories"
M.F. Cullinan, Study Team Leader and J.F. Ford – Road Inventory Engineer.
Published April 1984.

"Use of Road Inventories in Description and Analysis of Australian Urban Arterial Road Networks"
M.F. Cullinan, Leader NAASRA Roads Study and J. Ford, Acting Assistant Advance Planning Engineer.
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"Crushed Rock"
D.T. Currie, General Manager – Programs, Programs Sub Branch.
Presented at a workshop organised by the Crushed Stone Association at the Box Hill College of T.A.F.E., June 1984.

"Behaviour of Socketed Piles in Weathered Basalt"
R.S. Evans, Scientific Officer, P McDonald, Geotechnical Section Head and G.A. Worotnicki, Engineer, Materials Division.
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"Optimisation of Pavement Design and Construction Practices for Rural Freeways"
R.S. Gilmour, Assistant Materials Engineer, Materials Group.
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"Construction of Load Bearing Elements under Bentonite: Bored Piles in Weathered Rocks"
J.C. Holden, Research Engineer, Materials Division.
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"The Construction of Bored Piles in Weathered Sedimentary Rock"
J.C. Holden, Research Engineer, Materials Division.
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"Economic Analysis of different Bituminous Surfacing based on their Comparative Performance"
A. Kumar, Engineer, Materials Division.
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"Characterising River Gravels for Freeway Pavement Construction"
P.W. Lowe, Materials Engineer, and D.T. Anderson, Engineer, Materials Division.
Presented at New Zealand Roading Symposium, Wellington, August 1983.

"IASER External Evaluation of the Southern Highlands Rural Development Project: Second Round Roads"
D.S. Mansell, M.L. Williams and D.L. Bennett.

"Planning People and Uncertainty"
R.S. Matthews, Principal Environmental Officer.
Presented at the Twenty-sixth Australian Survey Congress, Brisbane, March 1984.

"Settlement of Embankments on Thick Compressible Soil"
P McDonald, Geotechnical Section Head, and D.J. Cimino Engineer, Materials Division.
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"Pile Settlement in Clay"
P. McDonald, Geotechnical Section Head, Materials Division, and P.J. Moore, Reader in Civil

Engineering, University of Melbourne.
Presented at the 4th Australia-New Zealand Conference on Geomechanics, Perth, May 1984.

"Healing the Scars – Creeks, Quarries and Cuts"
R. Niran, Landscape Architect.
Presented to the Australian Institute of Architects Conference, Melbourne, August 1983.

"Graphic Programming"
F.J. Pedelty, Superintending Draftsman and B.J. Sach, Draftsman.
Presented at the General Drafting Systems Users Group 1983 Conference held at Sydney University, December 1983.

"Transportation – New Technologies – Roads Design, Materials and Construction"
P.T. Ransom, Works Methods Engineer.
Presented at the Society of Automotive Engineers Seminar, Melbourne, July 1983.

"Asphalt Specifications Part 1 – Materials"
"Asphalt Specifications Part 2 – Production and Placing"
J J Rebbechi, Assistant Asphalt Engineer.
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Three Day Asphalt Seminar, Melbourne, September 1983.

"Sampling for a Local Roads Study"
E.N. Vincent, Manager, Traffic Operations, and Highway Engineer, NAASRA Roads Study.
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"The NAASRA Roads Study"
R.T. Underwood, Chief General Manager – Planning and Design.
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B.J. Fielding, Research Scientific Officer, Materials Division.