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The Development and Implementation of the Australian Accelerated Loading Facility Program

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ABSTRACT

The Accelerated Loading Facility (ALF) is a transportable, linear test facility with unidirectional loading and pavement measurement data-logging instrumentation systems. The first pavement trial was conducted on a heavy-duty flexible pavement in New South Wales from July 1984 to April 1985. The second trial is now in progress on a typical rural arterial flexible pavement with a chip seal at Benalla, Victoria. A research strategy is being developed to ensure that ALF trials contribute to broad research objectives and that the ALF program is integrated with other components of pavement research, including long-term monitoring.

The Accelerated Loading Facility (ALF) is a relocatable facility that applies controlled, full-scale wheel loads to sections of real pavement. ALF is now engaged in a program of testing and research, in cooperation with the National Association of Australian State Road Authorities (NAASRA). Contained in this paper is an outline of factors leading to the building of the ALF; its design, construction, and instrumentation; the first year of operation; and early results.

FACTORS LEADING TO THE ALF TESTING PROGRAM

The early Australian Road Research Board (ARRB) research on materials and layers demonstrated the complexity of material response and that a form of rolling-wheel test was needed. This led to the construction of a quarter-scale test track that produced useful results but that also exposed the limitations of small-scale testing. The NAASRA Economics of Road Vehicle Limits Study (1) contains a review of the costs and benefits of heavy vehicles that predicts the impacts, costs, and benefits of increased axle loads and different configurations. These predictions, although of vital importance, were based on limited local and overseas experience with heavier vehicles, greater traffic, thicker pavements, and stronger materials. The late 1960s and 1970s saw the construction of many kilometers of high-standard highway in Australia to carry heavy traffic volumes. The pavement designs and construction standards used were developed from previous experience of unbound bases with thin bituminous surfacings. Under some conditions, the performance of these new pavements was disappointing.

In 1979, the Principal Technical Committee (PTC) of NAASRA formed a working group to review pavement research needs and to recommend means for implementing the necessary research. The working-group review identified and strengthened the need for research into pavement materials and structural response to traffic loads, and recommended that these be studied at full scale with the maximum legal load (at least) being applied by a moving wheel to a pavement constructed of typical materials to normal dimensions

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and by common construction practices (2). However, it was also realized that the use of a full-scale ALF alone was not enough because this approach would not include time, climate-dependent, or multiaxle, dynamic load effects. It must be supported by field and laboratory studies.

It was decided by the PTC Working Group that a rolling-wheel test track was the type of facility needed to provide for accelerated testing under realistic load, material, and construction conditions for the Australian environment. The various means of achieving this were then examined in detail, several existing and planned overseas facilities were investigated, and a set of design requirements was developed (3).

BUILDING ALF

Design Considerations

The outline specifications finally adopted were as follows:

- A linear type machine,
- Loads up to 100 kN,
- A speed of test wheel of 20 km/hr,
- A length of test pavement of 10 m,
- Unidirectional, power-driven loading wheels,
- A transverse distribution of load paths,
- A suspension system to be of a uniform response type,
- An applied load to be monitored,
- A machine to be readily transportable between test sites, and
- A machine to be capable of operating for 10^6 load cycles without a major overhaul.

Mechanical Design

The layout of ALF is shown in Figure 1. The loading wheel accelerates down a curved ramp and is driven along the test length by electric motors on the wheels. At the end of the test length, the load trolley decelerates as it runs up a second curved ramp and the wheels are lifted clear of the pavement. The load trolley then runs down the ramp and is driven back to the start ramp by the wheels, still rotating in the same direction, running on the underside of a plate fixed to the machine frame. The applied load that can be varied between approximately 4 and 10 tons is measured by load cells in the trolley assembly. Further information on the mechanical design is given in Scrivener (4).

Electronic Design

Electronic systems are based on the ARRB-developed Microprocessor-Based Data Acquisition System (AMBDAS). An automatic control system operates the transverse distribution of load paths, logs operational data, monitors various machine states, and automatically shuts down the machine if certain preset conditions are not met. A monitoring system records the load and speed profiles for the pavement loading segment of an ALF cycle.

ALF has been patented by the DMR, New South Wales in Australia and in 19 other countries.

Instrumentation

The pavement measurements currently taken during a trial are as follows:

- A record of surface cracking,
- Transient deflections at the pavement surface,
- Transient deflections at depths within the pavement structure,
- Permanent deformation at the surface, and
- Permanent deformations at depths within the pavement structure.

At this stage, surface cracking is photo-logged and measured manually. Transient deflection bowls are measured with the ALF loading wheels moving at a crawl speed towed by winches mounted at either end of the main frame. Surface deflections are measured using a conventional Benkelman beam fitted with a transducer to provide an electrical output. Three different instruments for measuring deflection bowls at depth were employed in the first pavement trial. These instruments can also be used to measure permanent deformations at depth. The instruments are as follows:

1. Multidepth Deflectometer: This is the National Institution for Transport and Road Research (South Africa) design that measures deflections at a number of depths relative to a ground reference located well below the pavement surface.
2. Partial Deflection Gauge: This is an ARRB-designed instrument for measuring deflections at one depth relative to the surface. The transducer is only installed while measurements are being taken.
3. Multidepth Deflection Gauge: This ARRB-designed instrument (Figure 2) combines features of the other two. Deflections can be measured at up to three depths relative to a ground reference, or at four depths relative to the surface.

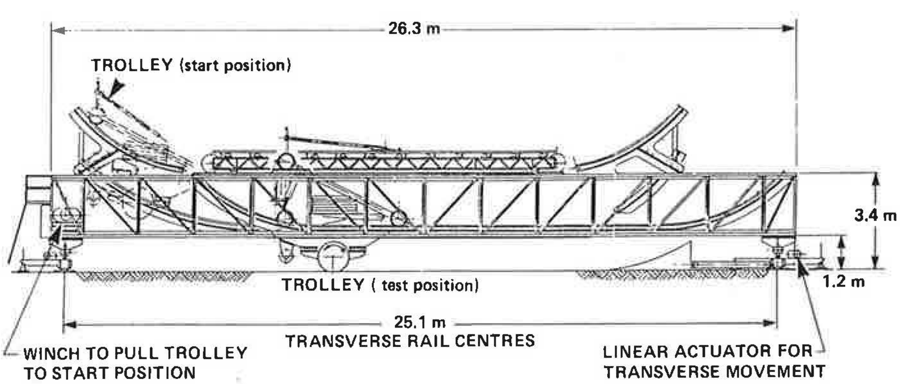

FIGURE 1 Operational layout of the ALF.

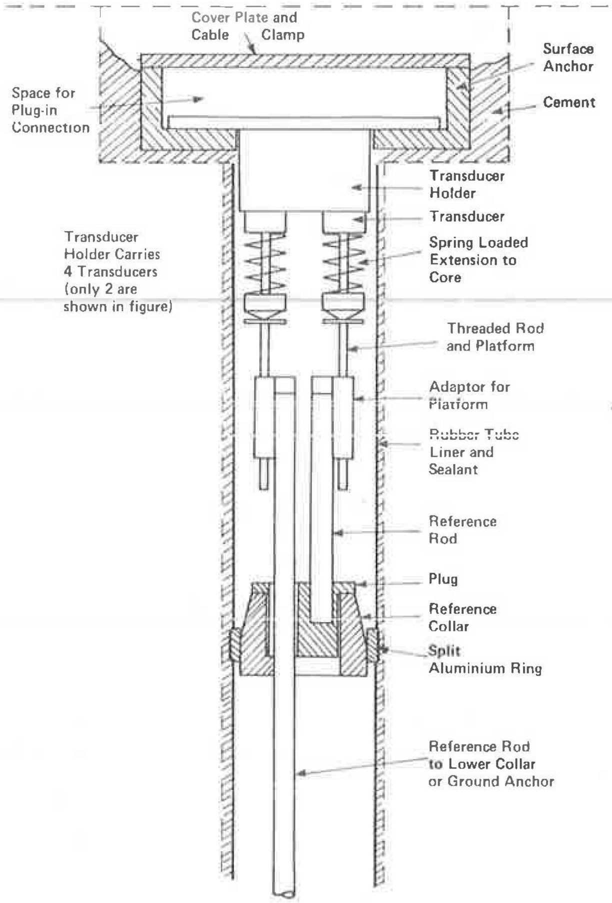

FIGURE 2 Multidepth deflection gauge.

Permanent surface deformations are measured as a transverse profile using an ARRB-designed profilometer. Rut depths corresponding to a standard straight edge can be computed readily from the profile. The large quantity of data that need to be regularly acquired to monitor pavement deterioration dictates the use of automatic data logging methods. The deflection and profile data are logged using a portable PRDAS (Pavement Response DAS) version of the AMBDAS system mentioned earlier. Up to 6 channels of data are digitized each time a pulse from the position-measuring system triggers the PRDAS. Thus, a series of data values are recorded as the loading wheel is slowly towed past the measuring instruments, or as the profilometer transverses the test section. The data are directly recorded onto a digital cassette in the PRDAS. The force and speed monitoring ALFDAS mentioned earlier is integrated with a personal computer that monitors machine performance to enable onsite checking of the load and speed profiles. Further information on the measuring instruments and data logging system are contained in Sparks and Brown (5).

Operation

Site operation is organized on a 23-hr day with 5 onsite staff working 3 shifts. For the first trial, there was a learning period of low utilization and the anticipated difficulties with a unique new and major piece of equipment; however, stable operation was achieved for the last 16 weeks of the trial with an average utilization rate of 53 percent. In the second trial, 69 percent overall utilization was achieved in the first 17 weeks.

THE FIRST PAVEMENT TRIAL

Selection and Objectives

The site, which is located at Somersby, NSW, was on a newly constructed section of freeway. The primary reasons for selection were as follows:

1. There was an ample cross-section allowing minimal disturbance to traffic operations;
2. The structure is typical of heavy-duty pavements currently being constructed;
3. There are good construction records and test data for the site; and
4. The nearest dwelling was at least 600 m distant. (Noise calculations indicate that noise levels could cause problems for 24-hr operation with dwellings at a distance less than about 400 m.)

The structure of the pavement is given in the following table:

Pavement Type	Nominal (mm)	Actual (mm)
Asphalt	70	90 ± 5
Graded macadam base (20-mm nominal size)	150	125 ± 25
Macadam subbase (75-mm single size)	200	160 ± 30
Lime-stabilized subgrade	200	200 + 20

This represents a strong pavement relative to normal Australian practice. Benkelman beam tests at 1-m intervals along the centerline of the test strip gave a mean maximum reading of 0.28 mm and a standard deviation of 0.03. Site selection, operational arrangements, and the test program for the first trial are described further in Youdale (6) and Kadar (7).

At this first trial, interest was directed to pavement testing and to the performance of the ALF.

The pavement testing objectives were to (a) assess the structural performance and estimate service life, (b) study the response to ALF loading, and (c) investigate the response to loads of different magnitude. Objectives related to the ALF machine were to (a) test ALF under realistic conditions, (b) establish experimental and operational methods, (c) test the pavement instrumentation, (d) establish data processing and data management systems, and (e) develop and establish the testing philosophy and methodology. In addition to the preceding short-term objectives, the Somersby Trial is part of a long-term monitoring program that aims at the investigation of the performance and behavior of flexible pavements.

Environmental Conditions

As the test strip had not previously been trafficked, the test was commenced with a preloading phase of about 10^4 load cycles at a nominal 40 kN. The load was then increased to a nominal 80 kN for the remainder of the test. Transverse profile, surface deflection, and subsurface deflection measurements were taken at regular intervals. The loading test stretched over four meteorological seasons. The absolute maximum air temperature measured was 43.5°C and the minimum 6.5°C. The rainfall was recorded daily and totaled 947 mm over 4 months.

Loading Sequences

Two different wheel loads were applied--40 kN for the first 9,000 cycles (preloading) and 80 kN for accelerated testing. The 40-kN load was applied for another 35,000 cycles after a major repair (to test the machine). Altogether, 44,000 cycles were completed with a 40-kN load. As this is less than 5 percent of the total, analysis is focused on the 80-kN testing.

The ALF does not apply uniform load to the test length (8); thus, dynamic forces were monitored at 100-mm intervals along the test length and their average and the dynamic load coefficient were computed (Figures 3 and 4). The data indicated two reasonably uniformly loaded sections where the maximum and minimum load is within 10 percent, from 0.0-1.4 m at 120 kN and from 6.0-12.0 m at 80 kN. Results following refer to these sections. The trial was ended after 760,000 cycles, approximately 11.5 x 10^6 ESA.

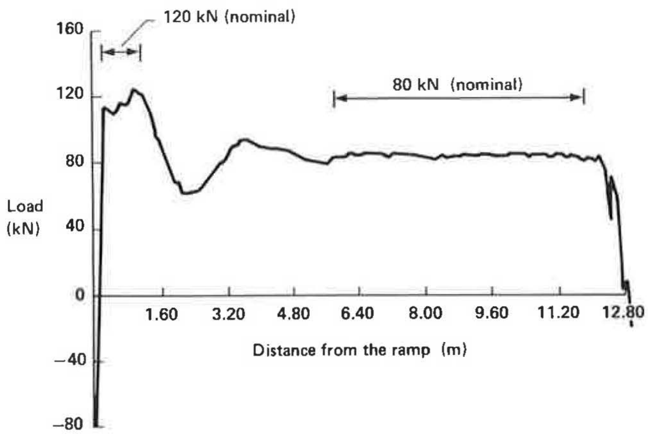

FIGURE 3 Mean dynamic forces.

Deflections

Surface deflection bowls were recorded at eight positions along the centerline of the test length. Figure 5 shows typical deflection bowls at the surface and at depths to 950 mm. The majority of the measurements were taken with an 80-kN load but some were taken with a 40-kN load, in order to relate the two. For the purpose of this report, the surface rebound deflection adjusted for temperature is used (see Figure 6).

Permanent Deformation

The transverse profile was recorded every 500 mm between chainage 0.5 and 11.0 with the transverse profilometer and converted to a rut depth under a 1.2-m straight edge. Pavement deformations followed

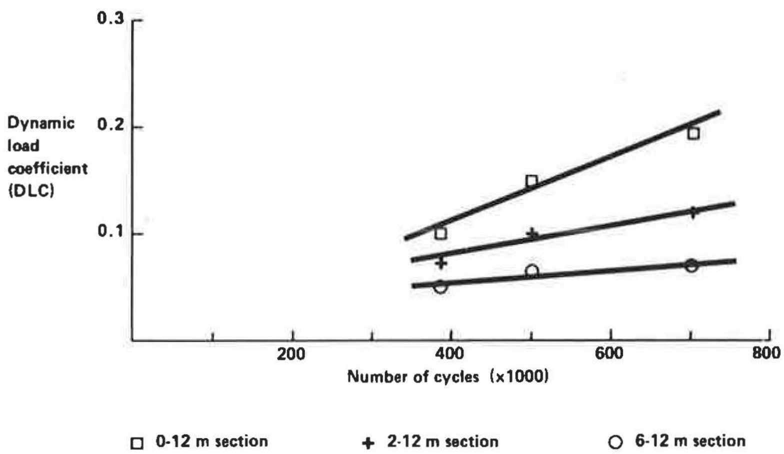

FIGURE 4 Dynamic load coefficient.

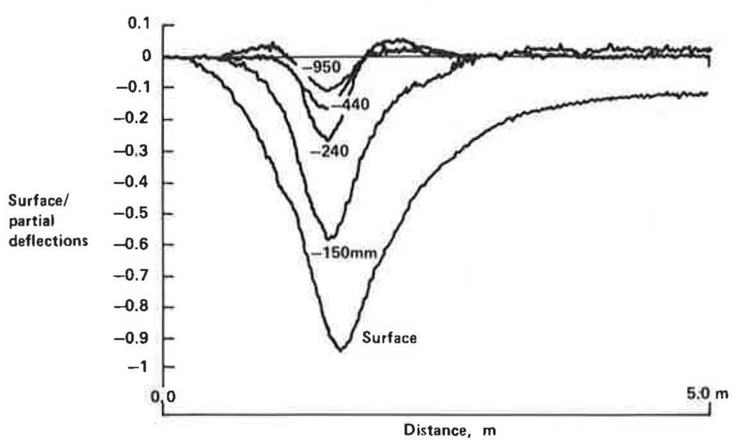

FIGURE 5 Typical surface and partial deflections—Somersby.

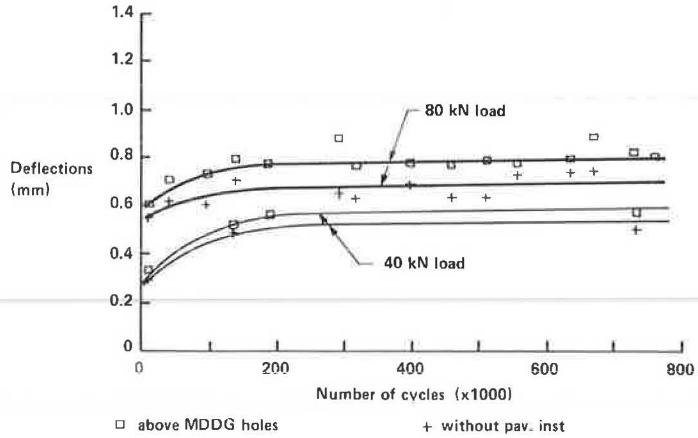

FIGURE 6 Temperature-adjusted surface deflections--Somersby.

a consistent pattern throughout the trial (Figure 7), which reflects the actual wheel load profile. The deepest representative rut depths (13 mm) were measured between 0.0 and 1.0 m in the area of the maximum (120 kN) dynamic forces. Pavement deformations of the uniformly 80-kN-loaded section (6.0-12.0 m) stabilized at about 5 mm after approximately 500,000 cycles, although under 120 kN, the deformations were still increasing at the end of the trial. (The maximum rut depths are shown in Figure 8.)

The preliminary analysis indicated exponents between 3 and 4 in the damage formula

$$D = (P/80)^d$$

where

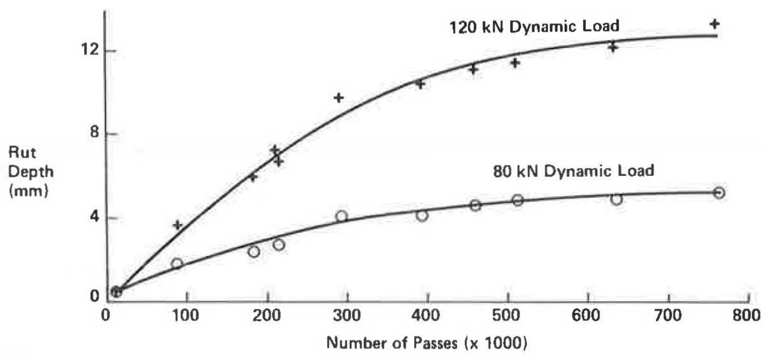

FIGURE 7 Longitudinal pavement profile—Somersby.

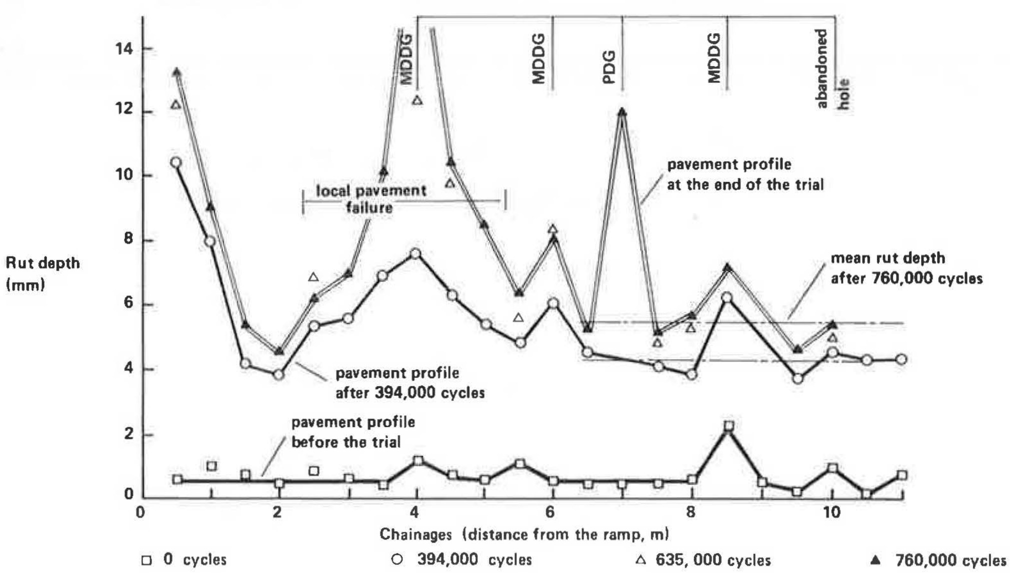

FIGURE 8 Rut depth versus number of load cycles—Somersby.

D = relative damage of axle load P to a rut depth of 5.0 mm,
P = axle load (kN), and
d = damage exponent (in this case, 3 to 4).

Further results of the first trial are given in Kadar (9).

THE SECOND TRIAL

Selection and Objectives

Having demonstrated the performance of ALF as well as establishing the operational parameters, a second site was selected to test a typical Australian rural arterial pavement. The site was again on a freeway section, not yet open to traffic with a pavement of chip seal, 200-mm fine-crushed rock base and subbase (20-mm nominal size), and 170-mm ripped sandstone-siltstone for the lower subbase. The principal objective was to establish the limit of performance of the pavement configuration.

Trial Progress

The trial has been running for 17 weeks (as of October 1985) and 760,000 cycles (12 x 10^6 ESAs) have been applied using 80-kN loads after a 31,000-cycle settling-down period at 40 and 60 kN. Temperatures ranged from 28°C to -6°C and rainfall totaled 338 mm over 4 months. Loading and deflection (Figure 9) patterns are similar to those of the first trial. No significant rutting has occurred to date. After 200,000 cycles, the surface seal displayed a distinct cracking pattern, and was resealed. No analysis has been conducted at this stage.

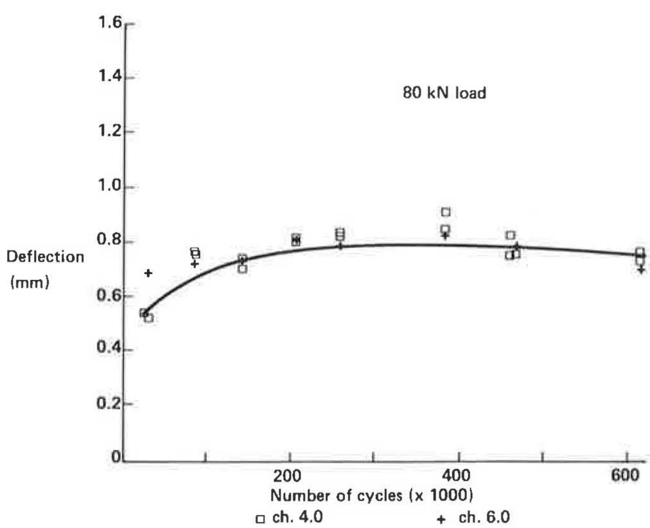

FIGURE 9 Temperature-adjusted surface deflections—Benalla.

THE RESEARCH STRATEGY

Early in its deliberations, the working group recognized that, for accelerated pavement loading tests to be effective in a research context, they must be combined with a broadly based research effort. The ALF tests are, accordingly, being integrated with other components of pavement research in Australia.

The broad objectives of the ARRB pavement research program are being developed under the following related headings:

1. Pavement Technology (includes the validation and refinement of structural theories and analytical models, and verification and improvement of design methods)
2. Pavement Management and Rehabilitation (includes the development of pavement life models and pavement management systems, and the performance of rehabilitation treatments)
3. Axle Loading (includes the effect of increased axle loadings on the rate of pavement deterioration)

Structural Theory and Models

Over the past two decades, considerable research effort has gone into the development of a structural theory of pavement behavior, which has provided the basis for mechanistic design methods. The CIRCLY model and the VESYS model are currently being used at the ARRB. The ALF tests will provide a valuable data base for checking pavement models. Once validated, these models will provide a means of extending and generalizing the findings from specific ALF tests.

Materials Testing

Samples from the ALF sites will be a substantial part of the ARRB materials characterization research effort. The results of standard tests will be provided by the host SRA. The ARRB contribution will include repeated load triaxial tests to determine resilient and permanent deformation properties of unbound and subgrade materials, and fatigue and modulus testing of asphaltic materials (10,11).

The material characterization data are necessary for comparisons between ALF test results and design models. In combination with detailed analyses of the pavement measurements, they will also allow a comparison of laboratory and in situ methods for estimating the mechanical properties of pavement layers.

Long-Term Monitoring

The primary purpose of pavement research must relate to the performance of pavements subjected to real traffic loading and environmental effects. Long-term monitoring of pavements subjected to ALF tests is seen as an essential component of the total program. This will include surveys of roughness, surface condition, deflection, and traffic loading. The results of the monitoring effort will enable pavement performance under real conditions to be related to performance under ALF loading, and an assessment of the contribution of time-dependent environmental effects. The ALF sites will be complemented by observations in road sections in all States (12).

CONCLUSIONS

The ALF has been designed, built, and operated as a major component of Australian pavement research. It is supported by laboratory and experimental road section studies. It requires long-term monitoring data for full validation. The first trial has been successfully completed by applying approximately 11.5 x 10^6 ESAs to a heavy duty flexible pavement over a period of 9 months. Results showed that performance was typical of the early life of a pavement--a marked increase in surface-rebound deflection quickly reaching a stable level (of about 0.5 mm under a 40 kN wheel load); and an increase in rut depth but at a decreasing rate. The relative rates of rutting for sections under different loads corresponded to an approximate fourth-power damage relation.

The second trial has reached 12 x 10^6 ESAs in 5 months and shows similar pavement deflection behavior. Insignificant rutting has occurred up to October 1985. Analysis has yet to begin.

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