THE ACCELERATED LOADING FACILITY AS
AN ACCELERATED LEARNING TOOL

Michael A Moffatt¹
BE (Hons) (Civil), M.Tech (Pavements)

Abstract
The benefits of an accelerated pavement testing program are often presented in terms of improvements to pavement design and analysis, the introduction of new materials and construction techniques and a better understanding of long term pavement performance. A highly significant and often overlooked additional benefit is the opportunity for staff training and learning. Although it is widely recognised that there is a current global shortage of skilled pavement engineers, pavement engineering represents only a small proportion of the curriculum at most tertiary engineering education institutions. The Accelerated Loading Facility operated by ARRB² Group has exposed student and graduate engineers to a wide range of learning experiences.

Introduction
The benefits of an accelerated pavement testing program are often discussed in terms of improvements to pavement design and analysis, the introduction of new materials and construction techniques, and a better understanding of long term pavement performance.

Proposals for new accelerated pavement testing (APT) facilities have focussed upon the need to verify existing pavement design and construction practices (1), a desire to quantify the effects of increased traffic levels and loads on an established infrastructure, and the use of alternative materials and treatments within pavement structures (1, 2). Economic analyses have demonstrated that Benefit Cost Ratios of completed APT research projects have typically exceeded four (3) and have risen as high as thirteen (3, 4). These analyses have focussed upon the road agency cost savings in terms of both asset establishment and asset preservation costs that have been realised as a result of the pavement design, construction and maintenance technologies and practices demonstrated by APT research work. The technological benefits of an APT program have been clearly demonstrated.

In Australia, ARRB Group uses the Accelerated Loading Facility (ALF) as an important tool in its research work. This paper briefly describes ALF, but rather than addressing the research benefits of the tool, focuses on the educational and training benefits that the facility provides. APT related literature is almost silent on the subject of educational benefit and it is hoped that this paper will contribute in this area.

¹ Michael Moffatt works with the ARRB Group Ltd
² Formerly the Australian Road Research Board
Accelerated Loading Facility

The ALF is used to apply a range of full scale axle loads to test pavements. ALF was designed and manufactured by the Department of Main Roads\(^3\), NSW in 1983. Since its inception four other ALFs of the Australian design have been manufactured (two are operated by the Federal Highway Administration in Virginia, one by the Louisiana State University in Baton Rouge and a fourth by the Research Institute of Highways in China). ARRB’s ALF is the only APT equipment operating in Australia and is used to assess:

- the estimated life of existing pavements
- the validity of new methods of pavement design and material characterisation
- the suitability of marginal, improved or innovative pavement materials
- the effectiveness of changes in pavement construction procedures
- the applicability of pavement rehabilitation techniques
- the effects of climate and traffic on performance.

When operating, ALF is 26.3m long, 4.0m wide, 5.7m tall, and weighs approximately 45 tonnes. The frame is transportable using a standard prime mover and a steerable rear bogey. It is electrically powered and is fully instrumented enabling it to perform continuous cyclic loading with little supervision. The load wheel is driven at approximately 20km/h and applies the test load to the 12m long test strip in only one direction (as some pavement materials are sensitive to bi-directional loading).

The half axle test wheel loads can be varied in 10kN increments from 40kN to 80kN (corresponding with the general mass limit through to 100% overloaded). The load wheel is lifted off the pavement at the end of each cycle and supported by the mainframe on its return. Using the conservation of energy as a key design principle, the machine is very energy efficient as it transfers kinetic energy into potential gravitational energy and back to kinetic energy in every cycle, in much the same manner as a pendulum. Two 11kW electric motors are used to ensure an even test speed and to replace the energy lost by the system as noise and friction (Figure 1).

![Figure 1. Dual test wheels, gearbox and 11kW drive motor](image-url)

\(^3\) Now known as the Roads and Traffic Authority
The loading can be channelised or applied over any transverse loading distribution up to 1.2m in width. A normal transverse distribution between 0.9m to 1.2m wide is commonly used to simulate traffic wander across the pavement. Since 1983, the load wheels have been limited to dual wheel or single wheels (including super singles) operating on a single (half) axle. An enhancement to ALF is currently underway which will allow loading with (half) tandem and triaxle groups.

The cycle time for each load is about 9 seconds, which corresponds to approximately 370 load cycles per hour or depending on the percentage of operating time, about 50,000 cycles per week. The principle of operation is that the structural life of a pavement is dependent on the applied axle loads and number of load cycles. For example, the standard axle load for pavement design purposes is 8 tonnes. ALF can apply an equivalent axle load of up to 16 tonnes (half axle load of 80kN x 2). The following formula is used to determine the damage caused by loads of different levels:

\[
\text{Pavement damage} = \left( \frac{\text{Load on test axle}}{\text{Standard axle load}} \right)^N \quad \text{(A)}
\]

The value of \(N\) is dependent on the type of materials used in the pavement construction, for example — granular pavements and subgrade = 7, asphalt = 5, cement stabilized = 12. If fatigue of asphalt (N = 5) was the object of the trial, then the damage caused by a single 16 tonne axle would be 32 times the damage caused by a single 8 tonne axle (equation B). Hence ALF can accelerate the testing during a trial by applying a heavier than standard axle load.

\[
\text{Pavement damage} = \left( \frac{16}{8} \right)^5 = 32 \quad \text{(B)}
\]

A value of \(N = 4\) is used to determine the number of Equivalent Standard Axles (ESAs) commonly used in road design and maintenance calculations.

Since its construction, ALF has completed over 32 million cycles at various loads representing 315 million ESAs. ALF trials have been conducted at various locations in Victoria, New South Wales, South Australia and Queensland. ALF has twice conducted long term testing near Beerburrum on the Sunshine Coast, Queensland (6). Whilst ALF is a mobile, relocatable machine, in recent years it has mainly been located at a permanent site in Melbourne, inside a large 54m x 20m building (see Figure 2). This has allowed much greater control of the moisture condition of the test pavement.

![Accelerated loading facility operating inside enclosed building](image)

Funding for projects which involve using ALF as a research tool has increased owing to concerns regarding the ability of an ageing pavement infrastructure to cope with the increasing demands being placed on it by new generation vehicles and the imminent introduction of performance based standards for heavy vehicles. Recent funding levels allow nine to twelve months ALF testing per year.
The focus of recent ALF research work has been the field validation of material characterisations and design methods and not on proof loading of pavement structures. As a result ALF research projects have a high component of associated laboratory work, often involving the development of new or the refinement of existing test procedures. Increased funding levels and the nature of the research work being undertaken has also seen a returning emphasis on pavement instrumentation. Upcoming projects will examine the effects of multiple axle loads on granular pavement performance and the performance of a foamed bitumen stabilised pavement.

ARRB also offers an ALF testing service to customers outside of Austroads to test various pavement designs, materials and treatments. ALF has been used to assess the performance of vehicle detection systems, and the relative performance of specialist truck tyres.

Pavement education in Australia

Generally, engineering courses at Australian tertiary institutions have had little focus on pavement engineering. Typically undergraduate civil engineering students have limited exposure to pavement engineering. The syllabus is usually limited to an overview of the terminology used and the rudiments of thickness design, generally with little focus on pavement material characterisation, distress types and mechanisms or long term maintenance and performance issues.

Traditionally, Australian road authorities have taken the lead in the training of personnel. However, since the economic constraints of the late 1980s, the imposition of staff ceilings and the emergence of corporatisation within agencies, road authorities have severely contracted their education and training role (5). In the mid-1990s, road authorities and industry formed a partnership to establish a pavement studies and research centre to at least partly address the gap in pavement engineering training. This centre, now titled the Centre for Pavement Engineering Education (CPEE), has largely focussed on distance-based, post graduate course work.

Australian universities currently undertake little pavement related research work and have had extremely limited involvement with the national pavement research agenda or APT program. Through ARRB and partly based on ALF research work, two PhD theses have been completed and another two are ongoing. These studies have all been conducted by members of ARRB staff and all have been on a part-time basis.

Graduate engineer program

ARRB has a graduate rotation program which involves gaining experience in the various research theme areas of bituminous surfacings, pavement technology, asset management and road safety engineering. As part of this program, graduates can undertake work experience with ALF.

The training offered by ALF is very broad and interesting and the exposure gained depends in part on the particular phase of the ALF program. All university graduates agree that their road related course work in civil engineering is not extensive and thorough, and that the ALF program has expanded their knowledge immensely.

The type of experience graduates and engineering students can obtain under the ALF program include:

- assist with day to day maintenance and ALF operation
- experience in time management, documentation and laboratory procedures including preparation of soil samples
- installation of instrumentation in the test pavement. Examples include embedded strain gauge systems and multi-depth deflectometers (MDD) (see Figure 3)
- understanding of pavement compositions, the performance of bound and unbound materials, the effect of confining pressures on material strength and the sensitivity of granular materials to changes in moisture content
• the ability to differentiate between good and bad data through an understanding of pavement characteristics

• documentation and photographic recording of test results

• planning and selection of construction plant such as rotormill/profiler, removal of existing pavements and construction and placement of the final surfacing

• blending of materials through a small local pugmill, and take part in discussions and testing to determine the appropriate amount of water to be introduced into the pugmill for each material

• undergraduate surveying techniques are strengthened in undertaking, processing and analysing the extensive construction surveys. This involved the use of laser levelling equipment

• moisture contents determination and subsequent laboratory testing

• graduates assist with collection of routine pavement condition measurements including transverse surface profile (see Figure 4), surface macro-texture, falling weight deflectometer, nuclear density meter and moisture content readings and oven dried moisture contents. They process and analyse the resulting data and provide recommendations

• the experience gained has allowed graduates to make broad predictions of likely pavement behaviour and became familiar with the early warning signs of pavement failure.
Candid comments from two civil engineering graduates and a civil engineering student

- **Involvement in the ALF program has given me a much better understanding of pavements and how they react to loading in the short and the long term. These pavement properties and the knowledge of them, underpin everything that happens at ALF to the point that you don’t actually think about it and it becomes second nature. In my ALF work I have been given a lot of responsibility, which is not taken lightly, and the results that have come from some of my work form a large part of a million dollar research program. As with lots of research, we were doing things that were not common and in some cases had never been done before. As such, often there wasn’t a clear guidebook to read or local experts to advise. This put the responsibility directly onto me to ensure everything worked and to think fast if it didn’t. Many of the skills I have learnt through the ALF program may not appear to be directly applicable elsewhere, however, taking a step back, the process of going through learning those skills is exceedingly valuable.**

- **The ALF program enabled me to see the entire life of a pavement, from construction through to pavement failure. Field and laboratory testing I have been involved with has given me an appreciation of pavement behaviour and valuable experience in managing personnel and equipment, including laboratory test programs. The wide range of experiences gained in a short period of time would be hard to obtain elsewhere.**

- **I was really impressed with the variety of work that I was able to do as part of the ALF research team. Fellow students doing vacation work were often stuck doing the same dull task over and over throughout their work. I had a much more interesting time.**
Conclusions
In a short period of time through the ALF program, young engineers are exposed to a range of activities for which they are often assigned responsibility.

Whilst many of these activities are commonly conducted throughout the road industry, it is considered uncommon for a recent engineering graduate to be exposed to such a range of activities within the first twelve months of their professional career.

In addition, the engineers gained experience and skill in more specialist areas such as the measurement of pavement responses to load using strain gauges and multi-depth deflectometer gauges, pavement trenching and related investigations and technical photography. The ALF program also proved to be an excellent environment for developing skills in project management, technical writing and communication.

Through their interaction with experienced pavement researchers and their own observations during ALF testing, young engineers would develop a ‘feel’ for pavement behaviour. It is considered unlikely that engineers unfamiliar with APT work would have a similar level of understanding at the same stage in their careers.

The graduate program has demonstrated that young engineers can benefit hugely from even short term involvement in an APT program and that there are many benefits realised from the process of involvement with APT in addition to those that are to be had from the research outputs themselves.

To date these learning benefits have been realised in an ad-hoc manner and solely by ARRB staff members. With a recent influx of secondments of road authority staff to ARRB, the opportunity exists for others to share in the benefits.

References


6. ALF-Beerburrum Trial. The Road Builders, Queensland Department of Main Roads. December 1986