

European Co-operation in Accelerated Load Testing – COST 347

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ABSTRACT: Investment in road construction and maintenance in Europe is at a very high level and any improvement will significantly affect the overall benefit cost analysis. An important way of analysing road pavements or maintenance options before commencing the expensive process of road construction is accelerated load testing (ALT). Traditionally, most ALT research has been conducted through national programs, but a Pan-European approach would be more efficient with regard to investment as well as acceptance of results. Since 2000, 17 European countries have been involved in COST 347 ‘Improvements in Pavement Research with Accelerated Load Testing’ under the European Commission with the main objective to harmonise the efforts of the individual European countries. The harmonisation was aimed at securing more efficient use of the ALT facilities in Europe through sharing of results, common testing methods and joint projects. In addition to the European countries, representatives from North America, South Africa, Australia and New Zealand have played active roles in COST 347 thus creating a world wide ALT network. The Final Report of COST 347 is now available and the results are impressive. The main result is a common code of good practice for the use of ALT, which ties together the results of the work in COST 347. The common code is seen as a major tool for improving European co-operation in ALT. Among the specific results from COST 347 are a catalogue of European ALT facilities, and a database of European ALT research projects and reference literature. The use of ALT in connection with other types of pavement research like desk studies, computer modelling, laboratory studies and test roads is discussed and finally a catalogue of ideas for future ALT applications is presented.

KEY WORDS: Pavement, accelerated testing, research, guidelines, international co-operation.

1 INTRODUCTION

Road transport is the most important mode of surface transport in Europe, and it is fundamental to its social and economic development. Many billions of euros are spent each year on European transport issues, and the majority of these are used to support the road infrastructure. Investment in road construction and maintenance is therefore very high and any improvements will have a significant effect on the overall efficiency of mobility in Europe. Accelerated load testing (ALT) or accelerated pavement testing (APT), as it is often referred to in other parts of the world, is an important tool for analysing the behaviour of pavements. It gives the closest possible simulation of in-service pavements and it can be used to give a rapid

and reliable indication of pavement performance under traffic loading greater than that experienced in practice.

Accelerated Load Testing of pavements (ALT) is the application of large number of heavy wheel loads to sections of specially constructed or in-service pavements to determine either the pavement response or to reproduce several years wear in a few weeks. This acceleration of trafficking is performed so that the performance of a particular pavement, or pavement material, can be assessed rapidly without waiting for failures of the real road or the airport runway. This allows engineers to determine the likely life of the pavement before building and for adjustments in design, choice of materials or in construction materials to be made at that stage. By this means they hope to use materials more efficiently and to know the future maintenance needs with more certainty (which assists in economic planning).

2 COST 347 'IMPROVEMENTS IN PAVEMENT RESEARCH WITH ACCELERATED LOAD TESTING'

2.1 Scope of COST 347

COST Action 347 'Improvements in Pavement Research with Accelerated Load Testing' was initiated in October 2000 under the European Commission's COST (CO-operation in the field of Scientific and Technical research) framework. The main objectives of COST 347 were to develop a code of common practice to optimise the use of APT facilities in Europe and to develop a climate that will lead to a more harmonised approach to accelerated load testing of pavements in Europe. This should will accelerate our understanding of pavement behaviour and thereby bring about improvements in pavement design, maintenance and materials.

COST 347 was a concerted European research Action that involved 17 European countries, with observers and corresponding members from Australia, New Zealand, South Africa and the USA. The technical requirements of COST Action 347 are described in a Memorandum of Understanding (MoU), which can be accessed through the COST 347 web site at www.pave-test.org. The Action began in October 2000 and was completed in December 2004.

2.2 COST 347 and ALT world wide

Throughout the world, there are over 40 ALT facilities, with the most important facilities being located in Europe, Asia, Australia, New Zealand, South Africa and the United States (Metcalf, 2004 and Sharp, 2004). The main European facilities are situated in Denmark, Finland, France, Germany, the Netherlands, Romania, Slovakia, Spain, Sweden, Switzerland and the United Kingdom. Many of the European facilities are under the management of organisations involved in the Forum of European National Highway Research Laboratories (FEHRL), which can influence and enhance the co-ordination between the approaches taken in different countries. These facilities represent major investments with high operating and installation costs that can be in excess of 5 million euro. Although they are expensive, the benefits generally outstrip the costs. However, research is often duplicated and results cannot be easily transferred between facilities. Consequently, there is a need to ensure that these facilities are utilised in the most efficient manner. The achievement of this goal will produce a climate for increased co-operation that will lead to:

- An increase in pan-European cost-sharing research ventures;
- Collaborative research ventures between the public and the private sector;
- A broadening in the base of non-owner organisations using ALT facilities;
- International co-operation with pavement research groups outside Europe.

The COST Action was highly appropriate as it made it possible for a large number of European countries to participate, and it also provided an opportunity for international observers to interact. Concurrent with COST 347, the TRB Committee AFD40 (formerly A2B09) on Full Scale and Accelerated Pavement Testing initiated a synthesis study to document *Significant Findings from Full-scale Accelerated Pavement Testing* (Hugo and Epps Martin, 2004). The synthesis provided opportunity for capturing information from ALT facilities throughout the world including the participants to COST 347. The synergy between TRB Committee AFD40 on Full Scale/APT and the COST Action is obvious and future sharing of information will benefit all.

2.3 Continuation of COST 347

In reality, COST 347 was the creation of a European ALT group and it would be a pity not to continue the group beyond the termination of the COST activities. At the European level the group could preferably continue as a FEHRL activity and at the international level via the newly formed US TRB subcommittee AFD40(2) ‘APT International Alliance Subcommittee’.

The following Chapters describe the main results of COST 347. More details can be found in the Final Report of the Action (COST, 2005) and at www.pave-test.org. The latter functions as a portal to ALT and it will be maintained after the termination of COST 347.

3 COMMON CODE OF GOOD PRACTICE

The development of a common code of good practice for the application of European ALT facilities is a key output of COST Action 347. A code, which could be applied universally, will improve the efficiency and quality of current ALT work, will harmonise the way in which testing is conducted and data reported and could assist in designing future ALT facilities. It would result in ALT data being used more widely and it should be an essential requirement for international co-operation that will stimulate European research.

An important issue in planning an ALT experiment is to ensure that the capabilities of the ALT facility are sufficient to achieve the research objectives. Some facilities are better suited for specific topics than others and, for this reason, it may be necessary to select a particular facility for some research projects. For other projects it may be sufficient to modify a facility. To aid this, and many other decisions, a set of recommendations have been developed for the items illustrated in Figure 1.

The common code of good practice gives guidance for the crucial stages of an ALT experiment. Figure 1 gives the sequence of events in an ALT study for which recommendations have been developed under the headings listed on the right hand side of the Figure as part of the common code of practice. In addition to these elements, recommendations have been established for safety and environment, staffing and economy. Each recommendation contains the title, aim, importance, mandatory actions, recommended actions as well as references to literature with practical examples related to the specific recommendation.

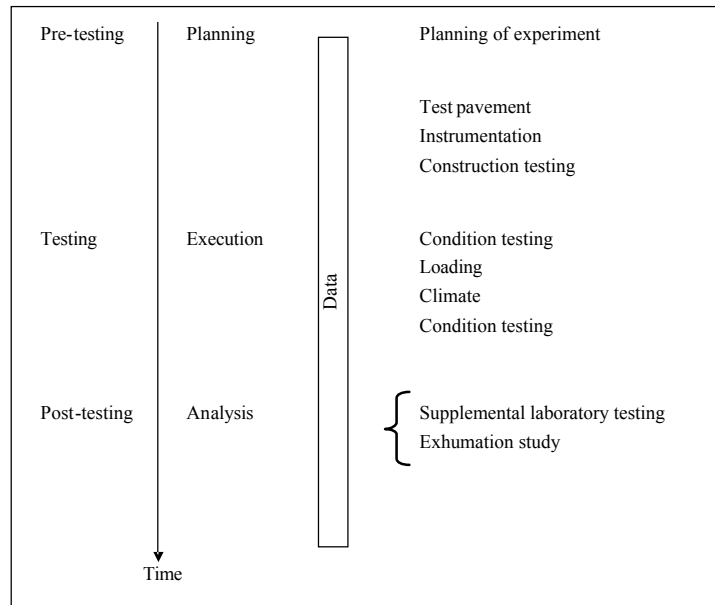


Figure 1: Sequence of ALT research. Elements covered by the common code of good practice.

The recommendations are intended to provide a general framework for ALT work rather than very specific practical guidelines. The reason for this is partly the diverse design of different ALT facilities and partly to avoid artificially constraining innovation.

4 ALT FACILITIES IN EUROPE

One of the COST 347 aims was to prepare a state-of-the-art review of ALT facilities in Europe. To meet this aim a database was prepared containing information collected from the different owners of ALT facilities together with descriptions of the present situation. The information covers:

- Characteristics of the ALT facilities;
- Pavement instrumentation;
- Pavement condition evaluation.

4.1 Characteristics of ALT facilities

The information regarding the ALT facilities was prepared as “fiches” with, as far as feasible, the same entries being completed for each facility. Each ALT facility “fiche” includes information about the dimensions of the facility, the loading system, axle configuration, testing speed, number of test sections in one test, environmental control facilities as well as measured variables. This information is supplemented with pictures and drawings as well as contact information.

A further objective was to identify the strengths, weaknesses, opportunities and threats (SWOT analysis) of the various facilities. These activities aimed to define the current situation of ALT in Europe and so provide a firm foundation for the other aspects of the COST 347 work.

The locations and a few statistics for the facilities from which the databases were compiled are shown in Table 1.

Table 1: Accelerated pavement load testing facilities in Europe.

Id	Location	Type of facility	Max tracking speed (km/h)	Loads per month (x 1000)
1	Lyngby, Denmark	Linear	25	50
2	Oulu, Finland	Linear (small-scale)	5	430
3	Delft, Netherlands	Linear	20	400
4	Sweden / Finland	Linear	12	600
5	Lausanne, Switzerland	Linear	12	400
6	Crowthorne, UK	Linear	20	500
7	Nottingham, UK	Linear (small-scale)	12	111
8	Madrid, Spain	Linear/Circular	60	100
9	Nantes, France	Circular	100	500
10	Iasi, Romania	Circular	40	51
11	Bratislava, Slovakia	Circular	50	170
12	Zürich, Switzerland	Circular	80	83
13	Bergisch Gladbach, Germany	Pulse Loading	-	1000
14	Dresden, Germany	Pulse Loading	-	12000

Information regarding the facilities can be found in the Final Report of the Action (COST, 2005) and at www.pave-test.org.

4.2 Pavement instrumentation

Pavement instrumentation is employed to measure the structural response of the pavement (stress, strain, deflection, etc) as well as material condition data (asphalt temperature, soil moisture content, etc). In order to measure these things in a reliable manner COST 347 determined that, at the very minimum, three gauges should be used to measure each response or condition. This overcomes problems of reproducibility that, often, is not high for much of the available instrumentation.

Modern data collection techniques and smart approaches mean that ALT users can now collect data in a responsive manner rather than focusing too much on the objectives of a particular ALT experiment. For example, pavement cracking might not be investigated in detail in a study primarily concerned with the overall pavement response, whereas an ‘intelligent’ and responsive approach allows information on secondary objectives to be gathered if it becomes available.

4.3 Pavement condition evaluation

Many different techniques are used to measure, monitor and interpret the forms of distress, and related issues, observed as a result of accelerated trafficking. Good practice in this area is to collect the following information:

- The thickness and the density of the asphalt and granular layers (during construction);
- Bearing capacity evaluations immediately after each layer is constructed;
- Use of the Falling Weight Deflectograph (FWD) before and after completion of a trial to measure surface deflection;
- Measurement of the deformed shape of the pavement with depth (achieved by exhumation at the end of the trial);
- Measurements of the development of permanent deformation and surface deflection during testing;

- Surface cracking information (this is normally achieved by visual observation, but there is a need to improve data collection procedures).

5 ALT RESEARCH IN EUROPE

This Chapter summarises the results and developments achieved through past and current research using ALT facilities as well as considering the socio-economic impacts of ALT research and how well ALT represents in-service behaviour. A set of suggestions for a future database of research results from European ALT facilities has also been produced.

Furthermore a literature reference list with over 700 titles concerning ALT research has been compiled.

5.1 Previous and current research in ALT

COST 347 compiled a database of over 70 summaries of experiments from European ALT research. From this database, an overview of previous and current European ALT research per main research topic was derived. These overviews give the reader easy access to related previous and current research on topics of interest. The information collected shows that a wide spectrum of pavement materials and pavement structures have been tested and/or compared in European ALT facilities over the past decade, covering a wide range of research topics. These included material testing, performance models, pavement design, pavement maintenance, wheel load effects, test validation, climatic effects and other research items. The results also show that most ALT facilities are, or can be made suitable for most of the research topics, which opens possibilities for a future more flexible use of the various facilities available in Europe.

The surveys also show that, since the eighties, ALT has increased in importance, probably because of the need for quick assessment of new and/or proprietary products and techniques and the move towards performance-related approaches for the introduction of innovations.

Table 2 gives the main research objective of a project and other topics that this project could help. For example, there were 45 projects whose main objective was to materials testing. Of these, 7 provided information relating to pavement performance models, 28 to pavement design, 7 to pavement maintenance, etc.

Table 2 shows that the majority of the projects involved materials testing and/or the development of pavement design methods. The topics relating to performance models, effects of wheel loads and test validation were mentioned

Table 2: Correspondence between primary and secondary research topics

	Total number of tests	Combined with testing of						
		Others	Environmental effects	Test validation	Wheel load effects	Maintenance	Pavement design	Performance models
Materials testing	45	0	1	15	12	7	28	7
Performance models	23	3	1	8	6	1	16	
Pavement design	48	3	2	9	12	6		
Maintenance	10	0	0	0	1			
Wheel load effects	23	1	1	9				
Test validation	21	0	1					
Environmental effects	3	0						
Others	4							

less frequently. Only a few projects were found to deal primarily with maintenance and climatic conditions. Usually research topics were combined in ALT experiments as shown in Table 2.

The importance of the various research topics has not changed significantly over the years. For all research topics, the total number of tests has increased more or less proportionally with time. However, in the future it is expected that environmental and sustainability issues like recycling and low energy material production will become key motives for ALT material testing. Pavement maintenance is also expected to gain in importance.

5.2 Outline of a future database on ALT research

The purpose of a future ALT research database would be to facilitate access to ALT results. The database would help with the systematic organisation and analysis of test results. It would also assist with the implementation of results, the planning of new research and improve ALT methodology. Therefore it could be useful for managers and researchers working in ALT facilities, as well as road administrators and engineers dealing with pavement design, performance, maintenance or management. For this information to be used efficiently it should be available on the www.pave-test.org web-site together with an annual overview.

5.3 ALT literature database

An ALT literature reference database was formed based on contributions from the COST 347 members and ALT facility owners operating in South Africa, New Zealand, Australia and the United States. Also the papers from the Reno APT Conference (1999) and the Minneapolis APT Conference (2004) were included. This resulted in a database of more than 700 references.

A statistical analysis of this database showed that the majority of publications dealt with using ALT to improve pavement design methods, followed by pavement performance models and materials research. The literature database is available at www.test-pave.org.

5.4 Benefits of ALT

Although they are probably the best argument for ALT activities, the economic benefits from ALT is often not (at least in Europe) reported. The large ratio by which benefits exceed costs has been demonstrated by several projects in which an analysis has been carried out, for example:

- Horak et al., 1992 obtained a benefit/cost ratio of 12.8 for an evaluation of the HVS in South Africa.
- Worel and Eaton, 2004 estimated that MnRoad produces a yearly savings of 21 million dollars for frost damage, and the yearly savings due to improvement of the design method at 2 million dollars. This is compared to the yearly expenses for MnRoad of 2.5 million dollars.
- For the Louisiana ALF, King and Morvat, 2004 estimate a total saving over 3 years of 8 million dollars based on life cycle analysis, against a total research investment of 1.5 million dollars.

The benefit/cost ratio of ALT can still be significantly improved by enhancing the effectiveness of ALT research. The key factors being improved communication concerning European ALT research, sharing of results and improved co-operation between European ALT facilities, universities and road authorities.

6 ALT AND OTHER TYPES OF PAVEMENT TESTS

6.1 The role of ALT in pavement research

The emphasis of ALT has shifted from its traditional role that was mainly concerned with pavement design issues towards maintenance of the pavements and surface defects. In addition to assessing maintenance solutions designed to minimise delays and hindrances of road works, ALT facilities are expected to be used in the future for testing of new and alternative pavement materials and assisting with the development of more environmentally friendly pavement solutions: quieter pavements, for example. Furthermore, increased private interest in the road sector is likely to spur an interest in ALT. In the open European market contractors will increasingly work across borders. This will result in materials and structures being introduced that are unfamiliar to individual European countries. This is likely to increase the need for ALT studies to develop and validate performance models to provide confidence in changes to conventional practice.

ALT can obviously be used for many different problems, and generally it will be included in an overall test strategy. This could involve the following activities with the choice and mix of these activities depending on the specific problem:

- Desk studies / literature surveys;
- Laboratory testing;
- Model calculations;
- Small scale ALT;
- Full scale ALT;
- RLT.

RLT is the assessment of full-scale pavement structures built into the road network and trafficked under the loading and environmental conditions prevailing at that site. These sections are either specially constructed to achieve different research aims or they are selected parts of the existing network. The important point is that these test sections are submitted to real traffic loading and climatic conditions. The relationship between laboratory tests, ALT and RLT is illustrated in Figure 2.

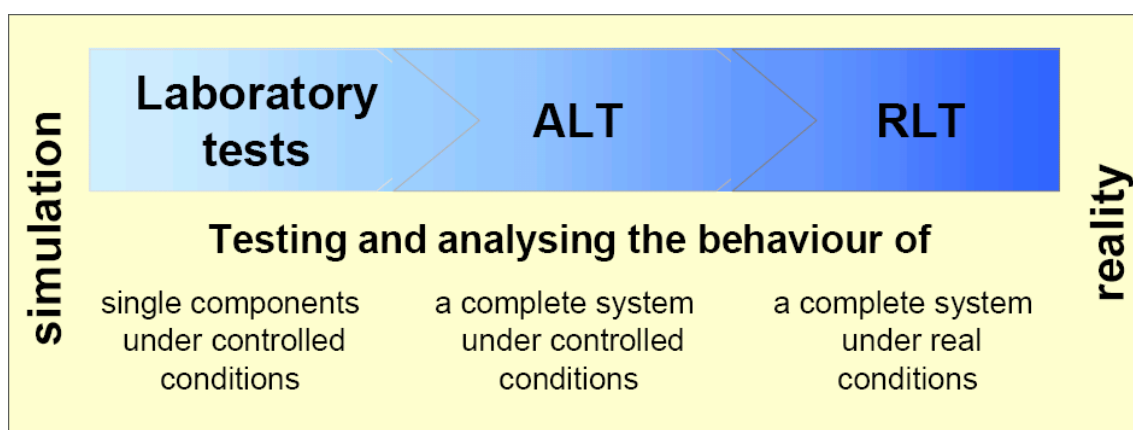


Figure 2: Engineering tools that bridge simulation and reality.

6.2 ALT versus RLT

ALT and RLT can both be used for complex examinations of road construction and for detailed pavement behaviour analysis. A SWOT analysis pointed out that ALT and RLT are very different tests that complement one another.

ALT operates under controlled environmental and loading conditions, which make it possible to use ALT to examine the influence of single factors on pavement behaviour. ALT experiments are also ideally suited to examine short term deterioration mechanisms, for example, freeze-thaw problems or rutting in hot weather. ALT is also suitable to assess the performance of innovative pavement structures and new materials relative to traditional pavements. ALT is also vital for the development of pavement design procedures and to validate analytical pavement response and deterioration models. It can also assist in the analysis of vehicle-road interaction: suspension, tyre type, etc.

RLT involves the complexities of realistic traffic loading and climatic and environmental conditions, which makes it almost impossible to isolate the influence of a single factor. As a result, RLT is suited long term studies and to establishing of empirical laws based on the performance of representative samples of pavement. These relationships can be used to calibrate pavement design procedures or to plan maintenance.

The main distinction between ALT and RLT is that ALT is accelerated, by using higher loads or number of repetitions, thinner structures or adverse climatic conditions, whereas with RLT acceleration can only be achieved by using thinner structures.

Each test type has its limitations, and the choice between ALT and RLT or a combination of the two will depend on the research topic in question. The development of robust transfer functions to relate the two forms of test is a challenge for research. The many variables and with complex interactions make this a demanding topic area. The different approaches that have been adopted internationally have been cited and discussed by Hugo and Epps Martin (2004). ALT and RLT are engineering tools which have to be combined with laboratory testing to gain more insight into pavement behaviour and the influence of experimental factors.

7 FUTURE USE OF ALT

To achieve the objective of identifying the most appropriate application of ALT in the near future, seven key topic areas have been identified. They are:

- Research into alternative and new road construction materials;
- New techniques for monitoring pavement material response, climatic influence, as well as pavement condition evaluation;
- Assessing suitability of different types of maintenance techniques;
- Evaluation of pavement environment related issues;
- Pavement design; methods and models;
- Effect of vehicle variables on pavement performance;
- Dealing with collaborative techniques, collaborative partnerships, harmonisation, reliability of results and scale factors;

The Final Report of COST 347 (COST, 2005) includes a table with 37 new pavement research topics, which can be investigated using ALT. The most important items to study are mix design, durability of pavement materials, maintenance and repair techniques, noise from tyre-pavement interaction, failure mechanisms, economic evaluation and warranty development.

8 CONCLUSIONS

COST 347 aimed at creating a climate for improved co-operation in ALT in Europe. The important conclusions from four year's work in COST 347 are:

- The common code of good practice is a necessary requirement for projects requiring international collaboration. To date, ALT research programmes have a poor record of international collaboration, however with the necessary protocols in place collaboration in Europe is expected to increase in the future as a result of the desire for more efficient use of facilities and scarce staff resources.
- The work carried out within the COST Action should continue. At the European level as an activity under FEHRL and at the international level via the newly formed TRB subcommittee AFD40(2) 'APT International Alliance Subcommittee'.
- The databases developed by COST 347 (facilities, research projects, literature, future research) should be kept up to date together with annual overviews. For this information to be used efficiently it should be available on the www.pave-test.org.
- Significant benefit-cost ratios can be obtained from ALT. Ratios of 10 or more are not uncommon. Benefit-cost analyses should be reported from all ALT studies.
- Both ALT and RLT have their limitations, and the choice between them or a combination of the two, will depend on the research topic. Research is urgently required to bridge the knowledge gap between these two forms of test.
- The role of APT is rapidly changing from pavement design issues to investigations relating to the maintenance of the existing, and often crowded, road networks. In coming years ALT projects are expected to focus on issues related to sustainability, new contractual relationships and European harmonisation.

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