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Fifty years of pavement research at Nottingham

A service to the asphalt industry

by Prof S F Brown

Introduction

To have sustained a major programme of research in asphalt pavement engineering over 50 years may be regarded either as a significant achievement or as an admission that many of the problems involved with the use of bitumen in roads defy solution. Having attracted over £20 million's worth of external grants and contracts (at 2004 prices), involving 89 projects, represents a huge achievement by the staff involved; but why have they not yet discovered all the answers? Well, the truth is that they have found some of the answers and, in so doing, made a major contribution to knowledge and engineering practice, which has brought an international reputation in pavement engineering to the banks of the Trent. Nottingham's research has also provided a service to UK industry and government, which is clearly apparent in many of the procedures, tests and general approach to asphalt pavement engineering often taken for granted today.

So, how did it all begin, who has been involved, what has it achieved and where is it going?

Early days

The Nottingham pavement engineering pedigree can be traced directly back to the invention of tar macadam, which symbolises the links with industry that the research team have always valued. The centenary celebrations by Tarmac a couple of years ago reminded us of the inventive and entrepreneurial talents of Edgar Purnell Hooley who was the county surveyor of Nottinghamshire at the turn of the 20th century. His blending of tar with slag to produce a dust-free road surface was first demonstrated on the famous Radcliffe Road, which runs on the north side of Trent Bridge cricket ground. The Tarmac story is well known but few people will realise that the first bitumen research worker at the University was the son of Hooley's district surveyor for the Newark area.

Peter (now Emeritus Professor) Pell, son of Jack, started work at the University as a research assistant in July 1954 on a project, funded by Shell, to investigate fatigue cracking in bitumen. Here then is the second link with a significant player in the asphalt industry and one which is very much in evidence today through the ten-year contract Shell placed with the University in 2001 to provide them with technical services in support of their business. The 50-year anniversary is, therefore, a double celebration. In 1950, the University of Nottingham appointed Joseph Pope as a professor to lead the departments of civil and mechanical engineering. Pope was a close friend of the then director of research for Shell, a man called Charlie Williams. Williams was very interested in university education and worked with Pope to develop special teaching equipment for use in schools. In the course of their discussions, Williams explained that the mechanical properties of bitumen were not well understood and Pope arranged for some simple torsion tests (which were not simple to conduct) to be performed in his laboratories. The tests must have been sufficiently successful, as Williams arranged for the University to be awarded a contract for investigating the fatigue cracking characteristics of bitumen and bitumen-sand mixtures. This was to be supervised by the senior civil engineer on Pope's staff, Dr Rex Coates, later to complete a distinguished academic career as head of civil engineering at the University and to become President of the Institution of Civil Engineers in 1978-79.

Peter Pell was a structural engineer working for Oscar Faber and Partners, having graduated at Nottingham in 1951 following war service. He was persuaded to return to his alma mater to take up the research post funded by the Shell contract for the princely salary of £700. He joined the academic staff two years later and the pioneering research he began was continued by other recruits and the link with Shell proceeded through a series of research contracts for 20 years.

Achievements

50 years is a long time and the range of research projects has been wide, a fact which has distinguished pavement engineering at Nottingham from that at many other institutions around the world which have focussed on narrower aspects of the subject. The interests of the staff, who have lead the research, have always focussed on the needs of pavement design and, in more recent years, of pavement rehabilitation. Thus, detailed research on materials has always had as its aim the need to study properties which are relevant to

performance in the pavement. A theoretical framework for design has been the basis for linking materials and performance but, while using theory, the research has been largely based on experiments and the development of appropriate testing facilities. Whenever possible the group has got involved in field work through special test sections of new materials and has developed extensive knowledge of pavement instrumentation.

An ongoing theme for many years, which went against contemporary thinking in government and industry, was the need to reduce empiricism in design and to focus on the mechanical properties of materials that relate to performance in the road. After many years of sniping at the attitudes of the establishment and suggesting alternative ways of dealing with pavement problems, it is enormously encouraging to see the general acceptance today of much which Nottingham had suggested over such a long period. One of the achievements has, therefore, been to act as a source of forward thinking in an international context and to stimulate ideas in those responsible for national pavement engineering policy.

At a more technical level there are several major areas of research which have directly led to improvements in practice to the benefit of the asphalt industry and to government. The following review is a selection and, in the interests of brevity, ignores influential work on pavement foundations, secondary aggregates and recycling, recent theoretical developments and diversifications into such matters as the soil mechanics of off-shore platforms and earthquakes and the mechanics of pebble bed thermal energy stores.

Analytical pavement design: Early work for Shell helped to demonstrate the validity of using linear elastic theory to compute stresses and strains in pavements as a basis for design; something that they implemented in their design charts and, more recently, in the computerised version of the charts. This research also demonstrated the limitations of assuming linear behaviour, notably for soils and granular materials, and led to a major research programme studying how these materials responded to repeated loading.

Nottingham were the first group to develop a computerised pavement design package, which was appropriately called ADEM, and was funded by ACMA. This work was extended to form an important component of the research that led to the publication of the famous LR1132 by TRL in 1984, which made the use of a theoretical approach to pavement design in the UK at last respectable. This research was also used in developing the Mobil Asphalt Pavement Design Manual, published in 1985.

An important spin-off from this research was the introduction of a ‘Simplified Pavement Design Method’ intended to teach beginners the essentials of the subject by demonstrating the vital link between pavement design and material properties. This involved the use of computers for teaching, but only once the students had done the sums by hand first. Many members of the industry who attended the regular BITMADE courses at Nottingham will recall the endless nomographs and charts with logarithmic scales that were so difficult to use. Thus do we appreciate the power of the chip!

As a consequence of Nottingham’s growing reputation, in 1978 the County Surveyor of Derbyshire invited the team to design a section of dual carriageway, using their accumulated research knowledge to see if the ratepayers could enjoy some savings. The result was the introduction of a stiff asphalt base, that provided improved stiffness and fatigue resistance relative to conventional DBM, a reduced sub-base thickness over a geosynthetic separator and a saving of 10% on initial cost. This approach presaged the introduction of DMB 50, HDM and the rest. The County chose surface dressing to complete the pavement but this failed during the first winter, thus leading to a bad reputation for the trial but the structural integrity of the pavement was demonstrated in later tests and the first moves had been made away from recipe specifications.

Asphalt mixture design: In 1979 Mobil started supporting the Nottingham work and this fruitful relationship lasted for 11 years. In addition to the pavement design developments, this research focussed on mixture design and mechanical properties. Initially, small changes to the recipes for HRA and DBM bases and basecourses were introduced that demonstrated a better balance of properties by improving the rut resistance of the former and the fatigue resistance of the latter. It was during this period that the unsuitability of the Marshall test was demonstrated before this was fully appreciated even in the US. A start was, therefore, made on evolving something better and more relevant to the role of the asphalt in the pavement.

The opportunity to assist with some mixture design problems in Dubai in 1987-88 provided the extreme conditions for focussing on an improved method of mixture design. This emphasised the importance of studying the effects on grading, binder content and compactive effort on mechanical properties but particularly on permanent deformation resistance.

The other significant development during this period of research was the introduction of the Nottingham Asphalt Tester (NAT), which evolved from more complex apparatus as a tool that could be of interest to the industry.

Asphalt testing: Following completion of the work for Mobil, a consortium of nine companies and 14 local authorities joined together with the Science and Engineering Research Council and the DOT to fund the BITUTEST project, the results of which have had a major impact on the industry. During this research, the NAT evolved in its various formats to provide a simple tool to measure the three key mechanical properties of asphalt mixtures. This combined approach allowed a wide range of laboratories to use the equipment and to explore its potential for the future. Draft standards were prepared and the rest is well known history.

Other aspects of this research included a study of mixture durability and the introduction of accelerated procedures for ageing and water damage. At that time (mid 1990s) there was little interest from the various partners in this aspect of the work but it took advantage of the major US effort then being concluded in the Strategic Highway Research Program (SHRP), in which the Nottingham team played quite a major direct role. Current work at Nottingham for the Highways Agency on development of the SATS test, combining ageing and water damage, shows how interests have changed.

Pavement evaluation: Conscious of the national need to move the focus from new build to maintenance, Nottingham's research in the early 1980s started to investigate the structural evaluation of pavements. Knowledge of research in the USA and on the Continent of Europe suggested that the best tool for testing pavements was the Falling Weight Deflectometer (FWD) but interpretation of the data presented problems. The Nottingham team used their knowledge of pavement analysis, combined with that from testing of soils and granular materials, to develop a back-analysis programme that represented a significant improvement on those then available elsewhere.

This development coincided with a major technology transfer development at Nottingham - the formation of SWK Pavement Engineering, which exploited this new knowledge and introduced the FWD to pavement engineering practice in the UK. This development has had the most significant direct and indirect impact on the industry of all those that have emerged from Nottingham over the years. As Scott Wilson Pavement Engineering Ltd, they continue to lead innovation in pavement and rail track bed engineering, working closely with the Nottingham team.

Geosynthetics in pavements: The Nottingham group worked with ICI Fibres in the early days of fabrics in pavements and demonstrated the requirements for the reinforcement function as opposed to that of separation between layers. This involved use of the pilot-scale Pavement Test Facility, introduced in 1974, and which, over the period since, has been invaluable as a means of testing various pavement configurations.

In 1981, the Netlon company (now Tensar International) introduced high tensile polymer grids to the industry and Nottingham were invited to join an international team to study its use in various civil engineering applications, including asphalt reinforcement. This was exciting pioneering work driven on by the inventor, the late Brian Mercer, and guided by the distinguished mechanical engineer, Sir Hugh Ford. The outcome was very successful and the Nottingham research strongly influenced the introduction of these new products to the market place. The support of Tensar International has continued over the years and is presently concentrated on the reinforcement of rail ballast in a project funded jointly with the Royal Society

Manholes and pipes: While most members of the asphalt industry will regard these items as a clear interruption to good asphalt paving, none the less manhole installations and pipes in trenches are a highway reality.

Two threads of industry-supported research have helped evolve improved practice for both these tools of the statutory undertakers. Two major projects, stimulated by the £200 million annual UK spend on manhole maintenance and supported principally by Stanton plc, now Saint Gobain Pipelines, were conducted and led to a new HA Advice Note on installation procedures. These were intended to avoid early life failure of the bedding mortar and later work provided guidance on overcoming the problem posed by the stiff nature of a chamber installation in a flexible road.

The British Plastics Federation supported research, which gave an insight into how updated specifications could be introduced for backfilling trenches with uPVC pipes in a more economic way.

Commercial testing services

Given the availability of advanced testing facilities and an independence of view, the Nottingham pavement laboratories have long been used by industry for special testing services. This work has covered a very wide range of topics but has often been involved with new products or the use of additives to enhance performance. Much work has been done on asphalt and also on various geosynthetics. In the 1970s interest in the use of asphalt for the cores of rock fill dams precipitated a testing programme on the deformation characteristics of the asphalt to check its compatibility with the surrounding fill.

With the state-of-the-art facilities now available in the new Pavement Research Building, the Nottingham Centre for Pavement Engineering plans to significantly expand this area of its work as a service to the industry.

The future

From 1956 to 1965, Peter Pell was the only member of staff with an interest in asphalt pavement engineering. He was joined in that year by Stephen Brown, who, like himself, had been a research assistant on a Shell contract. They led the research together until Andrew Dawson was appointed 18 years later. Since 1983, Stephen Brown has led the team which has expanded significantly to its present complement of five staff and a total population of about 40 people working on research projects, supported by grants and contracts worth £1.2 million per year.

The future looks secure, with new leadership in the form of Professor Andrew Collop poised to take over when Steve is required to 'access his pension' in 2005. He will be supported by Gordon Airey and Nick Thom on matters related to asphalt pavements, and by Andrew Dawson for unbound and recycled materials, with the laboratory managed by Murray Parry. There are ambitious plans to expand pavement engineering at Nottingham, so the future will be exciting and the activities of NCPE will continue to be of service and interest to the asphalt industry and profession for many years to come.