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Accelerated Load Testing of Derby Airport Runway

S.J. EMERY
Managing Director, Wallace, Emery & Assoc.
T.D. PETERSEN
Engineer, Department of Aviation

SUMMARY Accelerated load testing was conducted on the runway at Derby Airport. Using mechanical analysis techniques, the roller weight and tyre pressure were adjusted until the roller duplicated stresses and strains induced by the critical aircraft. The equivalent of up to four years of scheduled aircraft traffic was applied in a matter of hours to assess the residual life of the pavement.

List of abbreviations

CBR	California Bearing Ratio
DCP	Dynamic Cone Penetrometer
FMC	Field moisture content
LS	Linear shrinkage
MDD	Maximum dry density
OMC	Optimum moisture content
PI	Plasticity index

1 INTRODUCTION

An accelerated loading test was performed on the 11/29 runway at Derby Airport to assess the performance of the runway under future airline traffic. In this paper, the background to the test is given first, then the accelerated loading test is discussed. The pavement test sections and their performance are discussed, along with the practical implications of the test results.

2 BACKGROUND

The 11/29 runway is the main runway at Derby Airport, Western Australia. It is 1736 metres long, 45 metres wide, and is sealed. It has a history of distress, which has usually been load-associated. In 1976, the runway ends and a central section were repaired with 300mm and 150mm respectively of cement-stabilised basecourse material. In 1984, 1985, May 1986, and October 1986, various sections were patched, generally with 150 to 300mm of unstabilised basecourse material. The earlier patches were in the wheeltracks, while the later patches were predominantly within the central ten metres of the runway. In addition to these specific repairs, there has been continuous minor maintenance in the form of crack patching and bird-bath patching.

The result of this patching is that the wheeltracks are patched over almost the full length of the runway. Since most of the trafficking occurs in the wheeltracks, the performance of these patches will govern the future performance of the runway.

Existing design and test methods for runways in Australia were inadequate to assess the future performance and so an accelerated loading test, using mechanistic pavement design techniques, was used. In this test, selected patched sections of the runway were repeatedly rolled to failure using a test roller which had been loaded to closely duplicate the stresses and strains imposed by the critical aircraft. The equivalent of up to four years airline trafficking was put on in a matter of hours.

3 ACCELERATED LOADING TEST

In an accelerated loading test, a small section of pavement is repeatedly trafficked by a load which simulates the load of normal traffic. In a short space of time, trafficking can be accumulated on this small section equivalent to several years of normal traffic on the pavement, and the long term performance of the pavement can be assessed in quantitative terms. Accelerated loading tests are well-established on roads with machines such as the Heavy Vehicle Simulator (Freeme et al., 1982) and the Australian ALF - accelerated loading facility which is owned by NAASRA and operated by ARRB.

The use of accelerated loading tests on aircraft pavements is less common. The Heavy Vehicle Simulator has been used to evaluate the proposed design of a taxiway at Jan Smuts (NITRR, 1983), and a test roller was used in Western Samoa to evaluate a coral basecourse material (Department of Housing and Construction, 1985).

Accelerated loading tests are different in concept to the more familiar proof rolling of subgrades or pavements. In proof rolling, a limited number of passes are made with a very heavy roller to check for weak areas. In an accelerated loading test, the pavement is trafficked by either an aircraft or a roller loaded to duplicate the effect of that aircraft; the actual pavement performance under the equivalent several years of traffic can be rapidly measured.

3.1 Aircraft Load

At Derby, the critical aircraft in terms of load on the pavement was taken as the British Aerospace (BAe) 146. This aircraft was operating into Derby at between 33 and 39 tonnes along with Fokker F20 aircraft operating at between 25 and 31.5 tonnes (both had similar undercarriage configurations and tyre pressures). The critical aircraft load was 39 tonnes with a tyre pressure of 620 kPa. This will be the heaviest aircraft likely to be allowed into Derby Airport on any pavement concession (the use of Derby Airport by aircraft larger than Fokker F27-500 size is controlled by the Department of Aviation using pavement concessions).

3.2 Equivalent test roller load

A test roller was loaded to simulate the stresses and strains induced at the critical points of the various pavement layers by the BAe 146 aircraft.

To evaluate the stresses and strains imposed in each layer by the aircraft, the ELSYM 5 mechanistic analysis programme was used (University of California, 1972). An idealised cross-section of a patch was chosen from available data: seal/crushed rock basecourse/decomposed gravel subbase (the original basecourse material)/clay sand subgrade. The ELSYM 5 material parameters were determined using modulus-CBR relationships (Emery, 1987).

Table 1 Material parameters input to mechanistic analysis

Layer	Elastic Modulus (MPa)	Poissons ratio	Layer thickness (mm)
Seal	-	-	10
Base	230	0.35	160
Sübbase	170	0.35	130
Subgrade	85	0.35	semi-infinite

3.3 Mechanistic analysis

In setting up the mechanistic analysis computer programme, the stresses and strains were determined at the critical points in the layers of the pavement. In the unstabilised upper pavement layers, the critical parameter was stress (taken together with material properties to be expressed as a factor of safety, after Maree, 1982) at the midpoint of the layer. For the subgrade, the critical parameter was vertical compressive strain at the top of subgrade.

It was found that the subbase and subgrade were both severely overstressed and were to be considered the critical layers. To establish the test roller load and tyre pressure which induced equivalent stresses and strains in each of these two layers, repeated ELSYM 5 runs were made with varying values of roller weight and tyre pressure. It was found that a total roller load of 36.7 tonnes, evenly distributed over the four wheels of the roller, and a tyre pressure of 650 kPa would give equivalent stresses and strains in the critical layers of the subbase and subgrade (Table 2) and this was adopted for the tests.

Table 2 Induced pavement stresses and strains

	BAe 146-200	Test roller
Total mass (tonnes)	39.2	36.7
Tyre pressure (kPa)	620	650
Number of tyres on main gear	2	4
Base principal stress		
minor	229 kPa	226
major	551 kPa	574
Subbase principal stress		
minor	-33 kPa	-31
major	309 kPa	312
Subgrade vertical compressive strain (mm)	0.00262	0.00263

3.4 Equivalency of aircraft and roller trafficking

The loading of the runway was almost totally by scheduled airline traffic. General aviation traffic was too light to be of significance, and unscheduled airline traffic was a mix of aircraft types and weights. For the then current airline schedules, the cumulative loading imposed on the runway was determined as a summation of individual loadings by each aircraft. Using the standard movements-to-coverage ratios for dual gear aircraft and taking the varying aircraft and varying weights into account, the total weekly scheduled airline traffic (that is to say all the F28 and BAe146 movements) was found to be equivalent to five coverages of a BAe146 aircraft at 39 tonnes.

Since the test roller would be trafficking back and forth along a defined line in the test sections, it was considered that the roller movements-to-coverage ratio was one. Therefore five passes by the test roller was taken as equivalent to one week of total scheduled airline traffic.

4 PAVEMENT TEST AREAS

The choice of test areas was severely limited by the need to work within the constraints of the prevailing Method of Working Plan, and by the requirement to have any area which may fail during the test repaired at the end of each day to allow scheduled aircraft movements. Four test areas were selected on the western end of the runway which represented the various types of pavement profiles which exist (Table 3).

Area 1 is a section of pavement on the wheeltracks of scheduled aircraft. The areas selected for testing were patched in 1976 and 1985 and have not exhibited any significant signs of distress.

Area 2 is an unrepaired section outside the usual wheeltrack of scheduled aircraft, but still exhibiting signs of load associated distress.

Area 3 is a section of pavement with a 1986 patch which was partially excavated and flooded in an attempt to simulate wet season conditions.

Area 4 is a section of pavement within the wheeltrack of current scheduled aircraft traffic consisting of a 1984 patch with no sign of pavement distress and an unrepaired section exhibiting slight signs of distress.

5 Results

Pavement failure was defined as occurring when repairs were required to allow scheduled aircraft operations to continue. Plastic deformation of 15mm was taken as equivalent to pavement failure for this runway. At this deformation heaving between the wheels starts to occur and longitudinal cracks form on both sides of the wheeltrack. Considerable experience with this pavement has shown that extensive failure of a section of pavement with a 15mm of wheel rutting will occur almost immediately if repairs are not carried out. Although rolling continued until the deformation of the pavement was considerably greater than 15mm, a value of 15mm to describe pavement failure for this runway was supported by the test rolling.

5.1 Area 1 1976 Patch

The cement stabilized section was given 1000 passes which is equivalent to four years of current scheduled aircraft traffic. At the completion of the test, the maximum plastic deformation was 1mm. The test was terminated because a concurrently trafficked joint had failed badly with a wheel rut to a depth of 72 mm. This joint was between three patches, the first being constructed in 1970 followed by one in 1985 and the last in 1986 which was adjacent to the test area. In patching it was

TABLE 3 PAVEMENT PROFILES AND MATERIAL PROPERTIES

MATERIAL	PROFILE	DCP	LAB	CBR	OMC	FMC	LS	PI
	mm	CBR	SOAKED	UNSOAKED	%	%	%	%
AREA 1 1976 PATCH								
Seal	00-15							
Cement stabilized gravel	15-130		NA	NA	NA	NA	NA	NA
Brown gravelly clay sand	130-195		40	120	6.5	7.0	1.5	3
Red brown clay gravel	195-600+		50	100	7.3	8.7	5.5	14
AREA 1 1985 PATCH								
Seal	00-15							
Light brown crushed sandstone	15-255	88	170	200+	8.0	4.0	NIL	NIL
Brown gravelly clay sand	255-390	54	40	120	6.5	7.7	1.5	3
Red brown clay sand (some gravel)	390-600+	25	25	80	7.0	8.2	5.5	15
AREA 2 UNREPAIRED								
Seal	00-25							
Red brown silty sand laterite	25-95	48	80	120	7.5	8.5	4.0	11
Brown silt sand	95-255	22	25	110	5.0	8.2	0.5	4
Red brown clay sand (some gravel)	255-450/600	18	25	80	7.0	9.1	5.5	15
Lateritic gravel (coffee rock)	450/600+							
AREA 3 WET SEASON SIMULATION								
Light Brown sandy crushed sandstone	00-105	25	200+	200+	7.2	8.5	NIL	NIL
Red brown clay sand (some gravel)	105-450/600	27	20	70	6.8	11.5	5.5	15
Lateritic gravel (coffee rock)	450/600+							
AREA 4 UNREPAIRED								
Seal	00-15							
Red brown silty sand laterite	15-130	64	80	120	7.6	8.0	4.0	11
Brown gravelly clay sand	130-200	37	50	120	6.5	8.6	1.5	3
Brown silt clay	200-450	14	5	70	9.0	9.9	9.5	17
Lateritic gravel (coffee rock)	450+							
AREA 4 1984 PATCH								
Seal	00-15							
Light brown sand crushed sandstone	15-255	88	140	190	7.2	4.3	0.5	NIL
Brown silt clay	255-450	15	5	70	9.0	11.6	9.5	17
Lateritic gravel (Coffee rock)	450+							

NOTE a:Low DCP values are probably a result of low field densities; the test rolling and DCP CBR test on area 3 was knowingly performed at low field density to assist moisture penetration into the subgrade.

b:Laboratory CBR tests were performed on samples compacted at Mod AASHTO OMC, with compactive efforts of 98% and 95% of Mod AASHTO MDD for basecourse and subbase materials respectively.

impossible to achieve adequate compaction at the interface and such failures were not unexpected; this failure ws not considered relevant to the performance of the test sections and has been disregarded. It does, however highlight the limitations of patching as an effective or economic long term repair method.

5.2 AREA 1 1985 PATCH

The 1985 patch was given 1000 passes which is equivalent to current scheduled aircraft traffic for four years. At the completion of the test the maximum plastic deformation was 3mm. this test was terminated at this stage for the same reason as described for the area 1 1976 test area.

5.3 AREA 2

This unrepaired section was given 76 passes; at 62 passes the pavement failed with longitudinal cracks and plastic deformation of up to 17mm; at 76 passes the maximum plastic deformation had increased increased to 19mm. The number of passes carried out was equivalent to 12 to 15 weeks of current scheduled aircraft traffic. The test was terminated because the test section had significantly failed and required reconstruction prior to aircraft being permitted to operate.

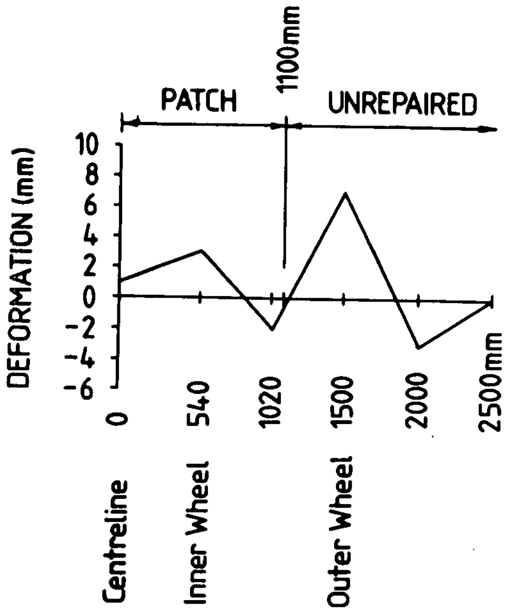
5.4 AREA 4 UNREPAIRED SECTION

This unrepaired section was given 200 passes which is equivalent to current airline traffic for approximately 12 months. At the completion of the test the maximum plastic deformation was 7mm (figure 1). The test was terminated at this stage because the pavement was deteriorating rapidly under test conditions and the need to reconstruct the pavement prior to the next scheduled aircraft movement.

5.5 AREA 4 1984 PATCH

The 1984 patch was given 200 passes (concurrently with the area 4 unrepaired section); an equivalent of 12 months of current scheduled aircraft traffic. At the completion of the test the maximum plastic deformation was 2mm (figure 1). This test was terminated when the adjacent area 4 section test had to be stopped.

Figure 1 Deformation of Area 4 after 200 Passes



5.6 AREA 3 1986 PATCH WET SEASON SIMULATION

This area was patched the previous day. The compaction of the patch was purposefully reduced to increase basecourse permeability. The patch was partially excavated and flooded in an attempt to simulate wet season conditions of partial or complete saturation in the layers of the pavement. The patch consisted of an average depth of 215mm of crushed rock over the existing subgrade. An average of 110mm of crushed rock was excavated to form a pool which was flooded for two hours. Further soaking would have been highly desirable, but was precluded by the requirement to reconstruct the test section for scheduled aircraft movements. The excavation reduced the pavement depth to 105mm reflecting the thinner 1984 and 1985 patches.

The unsealed soaked section was given 41 passes which is equivalent to 12 weeks of scheduled aircraft traffic. On completion of the test the maximum plastic deformation was approximately 42mm (there was some difficulty in measuring the deformation as the surface was unsealed); at 21 passes the plastic deformation was approximately 20mm. The test was terminated at this stage because the test section had failed.

The effect of soaking on bearing strength was monitored by taking DCP measurements before and after soaking. In the basecourse the initial DCP equivalent CBR results were low (24, 29, 21 for the three monitoring positions), but did not decrease with soaking (25, 35, 22). It was clearly evident that soaking had occurred but the non-plastic nature of the material meant that the bearing strength was not affected by moisture. The low initial CBR values were thought to be due to low compaction, since rolling of the test section was terminated prematurely in order to retain some porosity and assist in soaking the subgrade. The initial DCP CBR values for the top 150mm of subgrade were 36, 41, 37; after soaking this decreased to 20, 25, 27 suggesting that wetting had occurred in the upper subgrade. In the lower subgrade the initial DCP CBR values were 16, 15, 17; after soaking they were 20, 21, 14; indicating that moisture had not penetrated far.

The pavement failure in this wet season simulation appeared to be in the basecourse and was due to the action of the test roller and positive pore pressure associated with free water. However the usual failure mode in this runway is moisture associated loss of bearing strength in both the basecourse and the subgrade with the basecourse remaining generally unsaturated. Such a failure mode is quite separate and distinct from the positive pore pressure failure produced by the test, and it is considered that the failure in the basecourse did not reasonably simulate the wet season condition.

The wet season simulation was considered unsuccessful. The only conclusion that can be drawn is that the performance of the runway in the wet season is likely to be worse compared with the dry season performance; but this could not be quantified. In practical terms it is unlikely that the wet season conditions can be artificially simulated. The accelerated load testing would have to be conducted during the wet season to accurately measure pavement performance.

There was no testing of the unrepaired sections under simulated wet season conditions. However the basecourse materials sampled were a decomposing lateritic clay gravel with a soaked CBR less than that desirable for aircraft pavements. Laboratory tests showed that the subbase and subgrade materials sampled had a dramatic loss in bearing strength comparing soaking with unsoaked CBR results (Table 3).

6 CONCLUSIONS

Accelerated load testing may be used to quantify pavement performance under extreme overload conditions; a result which cannot be obtained from current design or test methods. The simulation of wet season conditions during the dry season was found to be impossible within the time constraints and a series of tests through out the year would be required to obtain non-dry season data. A disadvantage of this test method that it is destructive and test sections must be reconstructed on completion of testing.

The results of the accelerated load test have been used to develop and justify a Programme of maintenance, and to give guidance for the approval of pavement concessions.

The accelerated load testing showed that the patched areas gave good performance and the unrepaired areas performed poorly in the prevailing dry season. The laboratory analysis of the sample pavement materials indicated that their wet season performance will be significantly worse. The implications for airline operations are that a continuation of the current scheduled aircraft traffic wil not generate failures in the patched areas for several years. However, this traffic will cause failures within as little as 12 to 15 weeks in the unrepaired areas. Provided the current wheeltrack patching is extended to the full length of the runway, operations at the present weights and frequency will result in continuing minor maintenance and occasional major maintenance, but permanent runway closure is not envisaged in the short term.

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