AUCKLAND INTERNATIONAL AIRPORT - R3 RUNWAY RECONSTRUCTION

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INTRODUCTION

During April 2002 approximately 16,000 m^2 of the main runway at Auckland International Airport was reconstructed as part of the R3 reconstruction project. This involved the excavation and removal of the existing concrete slabs, cement stabilisation of the remaining hardfill and placement of 9,500 m^3 of high performance concrete. The final 8,000 m^3 was placed in 6 days with continuous supply from an on-site batching plant.

Auckland International Airport has converted a parallel taxiway for use as a temporary runway, and this was used for all aircraft operations during the R3 reconstruction. Closing the main runway caused considerable disruption due to reductions in runway lengths and operational capacity. A tight construction programme was therefore developed with no scope for extensions or delays.

This paper describes the background and design of the R3 runway reconstruction, and the logistics of construction within this tight time frame.

AUCKLAND AIRPORT BACKGROUND

Auckland International Airport was opened in 1966 with aircraft pavements comprising of a single runway, parallel taxiway and associated apron hard standing areas. All aircraft pavements are constructed from unreinforced concrete slabs.

The runway was extended in the early 1970's together with additional taxiways, and then since the early 1990's additional expansion has taken place at the airport including the construction of additional taxiways, apron hard standing and additional remote aircraft parking areas.

Auckland International Airport is New Zealand's busiest airport, currently handling over 147,000 aircraft movements per year, with over 186,000 tonnes of freight and over 8.4 million passengers per year. This includes both Domestic and International. The range of aircraft at Auckland International Airport varies from the largest International Boeing 747-400 series jets all the way down to small general aviation and run-about aircraft.

The airport is serviced by the single main runway which has a length of 3,635m. Aircraft can depart the main runway through two parallel taxiways and a series of interconnecting taxiways, speed ways and taxiway stubs all connected to the International and Domestic terminal aprons.

The layout of the aircraft pavements at Auckland International Airport are shown in Figure 1 below.

The concrete pavements are now generally over 35 years old. They have exceeded their original design life and the majority of trafficked slabs have failed with longitudinal fatigue cracks. In the more heavily trafficked areas, transverse cross cracking has also occurred.

RUNWAY PAVEMENT MAINTENANCE AND DESIGN

Aircraft apply load to the concrete pavements through direct vertical wheel loads. The concrete slabs bend under these loads, and tensile stresses and strains are developed at the base of the concrete slab. Unreinforced concrete pavements are designed by taking into account a variety of aircraft loads that will be applied over the life of a pavement and compare this to the available strength of the concrete slabs in flexural bending. The ratio of applied load to the available resistance results in the number of passes or design life.

A common misunderstanding is that landing aircraft apply the greatest load to the pavement. This is not true. The highest loads are applied when the aircraft is at its greatest weight and this is prior to take off when the aircraft has a full fuel load. Up to 40% of the total load may be in fuel and on landing the majority of this weight has been used up.

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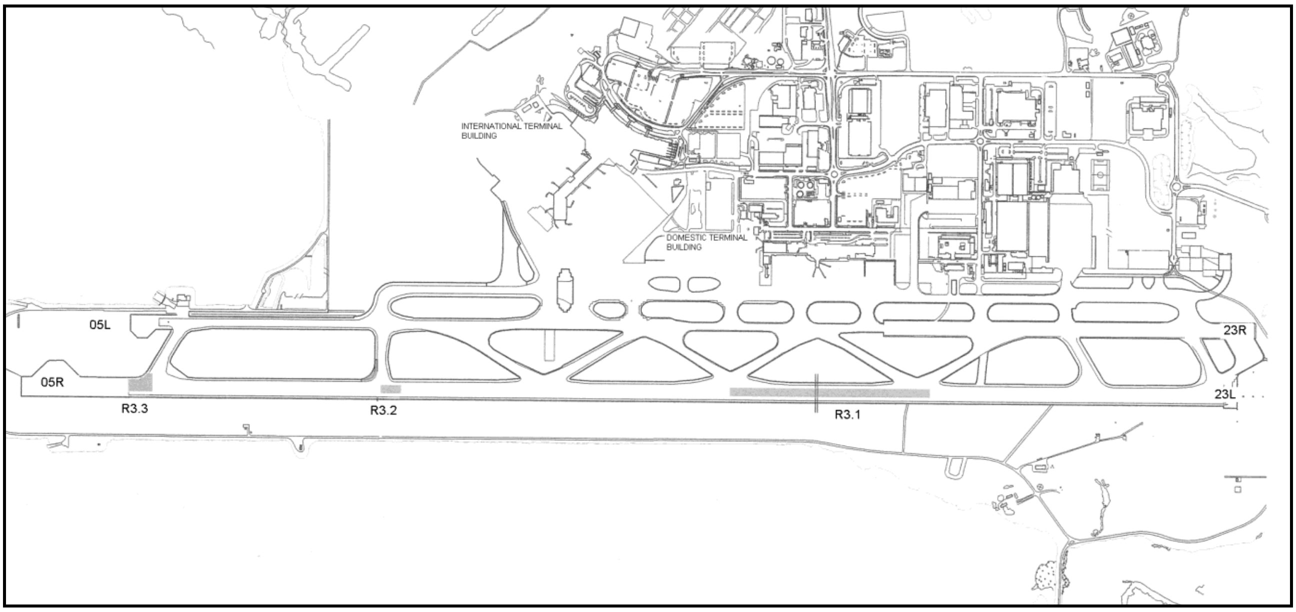


Figure 1 – Aircraft Pavements at Auckland International Airport

The original concrete pavement slabs at the airport vary in thickness from 305 to 355mm, constructed over various hardfill layers with a total pavement thickness of approximately 1200mm. The original 1966 pavement design was based on a theoretical aircraft similar to the Boeing 707 operating at that time, but with approximately double the wheel load. It was typical at the time to have a design life of about 20 years, and so it is clear that 35 years on and with the huge advances in aircraft design and size since the 1960's in fact the pavements at Auckland Airport have done well to last and be maintained for this time.

A program of pavement inspection and maintenance has been in place at the airport for some time, and specifically Beca have been involved since 1990. All pavement areas have been modelled and analysed and the remaining life of the concrete pavements predicted. These predictions have been tailored to follow the actual fatigue distress observed.

In 1998 Beca were commissioned by the Airport Company to look into alternative methods for reconstructing the failed concrete pavements. Some critical areas had already been reconstructed at both ends of the runway with conventional slab replacement, but as the areas towards the centre of the runway now required rehabilitation this study was required to investigate the options available to do this.

The study looked at trends for pavement reconstruction around the world including airports throughout the United Kingdom, America, Asia and Australia. A shortlist of methods applicable to the concrete pavement and single runway at Auckland International Airport was prepared and the advantages and disadvantages of each method weighed up. Some of the options considered included the use of asphalt to reconstruct the failed pavement areas and even the use of rapid setting concrete. Options also looked at the possibility of moving aircraft operations to an alternative area whilst the original area was reconstructed.

The final rehabilitation option selected was a mixture of some of the above options and comprised converting the existing parallel taxiway to become a new temporary runway and using this temporary runway for all aircraft operations while the original main runway was reconstructed using conventional concrete replacement techniques.

Some of the advantages of the concrete replacement option included matching the construction type of the existing concrete runway, a reasonably long design life compared to asphalt surfacing with minimal maintenance requirements during that life, and also as part of the temporary runway conversion failed areas of the taxiway could also be replaced.

The pavement design for the new reconstructed concrete pavement involves excavation of the old 300 – 355 mm thick concrete slabs, excavating an additional up to 200mm of existing scoria hardfill, cement stabilising the remaining hardfill insitu to a depth of 200mm and constructing new 500mm thick unreinforced concrete slabs above this. These new pavements are designed again for a theoretical aircraft, based on the current Boeing 747-400 aircraft layout but with a predicted future all up weight of 450 tonnes. This converts to individual wheel loads of approximately 26.7 tonnes. With this concrete pavement design an operational design life of up to 40 years is expected.

An important part of the pavement design is the material properties of the concrete placed. Pavement analysis has been based on a flexural strength requirement of a minimum of 4.8 MPa and an average flexural strength of 5.3 MPa at 4 days.

JOB SCOPE AND DESCRIPTION

The R3 runway reconstruction involved three separate areas of pavement construction on the main runway. In March and April 2002 a total of 521 runway slabs were replaced. 84 of these slabs were replaced in a western area termed R3.3. A further 41 slabs were replaced in an area part way down the runway from the west end termed R3.2 and in the main area a total of 396 runway slabs were replaced in R3.1. These areas are also shown on the plan in Figure 1 above.

R3.3 was undertaken in March 2002 in a 19 day construction period with conventional airport operations on the main runway running under displaced threshold. Effectively the runway is shortened to allow operation on the main runway but allowing reconstruction of the R3.3 runway slabs while aircraft operations continue overhead.

On April 6 2002 temporary runway 05L/23R was used for the first time. For up to 30 days all aircraft operations would use this temporary runway while areas R3.1 and R3.2 were reconstructed. The use of a temporary runway for this extended period is believed to be a first in the southern hemisphere. The construction work would take place on a 24 hour a day basis and no program overrun would be acceptable.

FACTS AND FIGURES

The temporary runway designated 05L/23R provided runway lengths varying between 2,910m and 3,110m, a reduction from the main runway with its 3,290m to 3,635m length depending on 05R/23L operations. Capacity on the temporary runway is lower than that of the main runway due to reduced side clearances, lack of high speed turnoffs and a single taxiway system. The reduction in aircraft movements was expected to drop from the usual 38 or 40 to approximately 30 movements per hour.

The total number of aircraft movements during the period of reconstruction in April on the temporary runway was approximately 8,730. The average Monday to Friday daily aircraft movement total during the work was 400. The busiest day recorded at 424 aircraft movements in a 24 hour period. The maximum runway hourly capacity achieved was 36.

Each slab is approximately 6 metres by 6 metres in size and weights approximately 26 tonnes. In the main April construction period with the 437 slabs removed the total mass of concrete excavated was over 11,000 tonnes. 19,200 tonnes of new concrete was reinstated with 8,000 m^3 of concrete placed in 6 days. The on-site batching plant worked continuously 24 hours per day with rates of pouring exceeding 750 m^3 on some 12 hours shifts. The concrete was poured at an average rate of 54 m^3 per hour.

The main April project was completed within a 23 day period, 7 days ahead of schedule. That the job was successfully completed well within programme is a testament to all the parties involved in this contract.

SITE SPECIFIC SECURITY AND CONTROL

Working “airside” i.e. within the security perimeter fence surrounding the runway, at a busy international airport means total compliance with a range of security and safety issues.

Auckland International Airport’s security team strictly controls access to the site, and regular visitors have to gain a security clearance. All drivers have to be trained in airside driving and pass a test, and each vehicle accessing the site needs to be approved and registered with security.

The most obvious hazard is aircraft, moving or stationary, and everything else gives way to them. A large jet can generate a massive jet blast extending back 200m or more, and objects in this area run the risk of being overturned or moved. This was particularly a concern during the construction of R3.3 on the runway threshold. Heavily laden 747 jets needing the full runway length would run up their engines within 100m of the site. A blast fence greatly reduced the effects but the site would still have to be cleared during this process.

Jet engines are particularly vulnerable to foreign object damage. Even paper and plastic can cause potentially disastrous damage. Very tidy house keeping and worker awareness meant there were not problems from the site.

CONSTRUCTION WORK ACTIVITIES

The following activities took place in the R3 runway reconstruction.

The first activity is saw cutting of the existing old runway slabs into small enough pieces for large loaders equipped with forklift arms to lift each slab in one piece and deposit it on a waiting dump truck. The old concrete is stored adjacent to the site and is to be crushed and reused as granular backfill. Excavators then remove the additional insitu hardfill material and trim to the new excavation base level.

The hardfill area is then cement stabilised to a depth of 200mm insitu with first a layer of cement spread on the hardfill surface at 5-7 % by dry weight and this material hoed into the hardfill and recompacted. A series of runway and taxiway lights and cable ducts are then reconstructed to replace those removed.

Finally the new 500m thick concrete slabs are poured with a series of keyed and dowelled concrete slabs. The concrete slabs are poured with lines of formwork set up to allow hit and miss pouring of the slabs. Finally the concrete slabs are water cured and the light fittings are replaced.

MIX DESIGN TESTING

Mix design and concrete testing were carried out by Firth Industries in advance of the project commencing. The design required a 4-day flexural strength for each sample of more than 5.3MPa with no individual result to fall below 4.8 MPa.

Although Firth had supplied concrete to other portions of the runway less than a year earlier, two significant changes had taken place; the time to achieve the required flexural strength had reduced from 7 days to 4 days, and the basalt aggregate was no longer available. This necessitated a new round of testing to prove a mix design.

It was agreed that the mix should be kept as simple as possible to minimise risk, and the attainment of flexural strength was to rest on good mix design, quality aggregates and a suitable GP cement content.

Strong, clean greywacke stone was tested with four types of sand in full size trials along with comparative testing of low and mid-range water reducers. Since temperature has such a large effect on early age strength, temperatures and handling for the trials were kept as similar as possible. No effort was made to duplicate the expected raised temperature due to the heat of hydration in the actual pour. A washed greywacke manufactured sand proved to be the best performing sand.

A full scale test slab was then constructed at the airport so that insitu concrete strengths could be measured and also construction methodology and finishing techniques could be trialled. Cylinder and beam specimens were formed from the fresh concrete and were tested at 4, 7 and 28 days. A series of concrete cylinders were also cored and beam samples were cut from the slab for flexural testing. These samples were taken approximately 1-2 days age when they could be cut. The comparison of test results from the cored and cut samples to those of the formed samples is evident in Table 1.

	4-day	***7-day***	***28-day***
Average Compressive Strengths, MPa			
Formed Cylinders	38.0	46.5	56.0
Cores cut from top of slab	29.7		
Cores cut from bottom of slab	43.4		
Average Flexural Strengths, MPa			
Formed Beams	4.8	5.4	6.1
Beams cut from bottom of slab	6.1		

Table 1 - Test Slab Results

CONCRETE CONSTRUCTION

After all tests and trials had been successfully completed Firth and Brian Perry Ltd were then all set for the main construction to start. The key to the project would be to consistently supply the high quality concrete.

The concrete placing contractor, Brian Perry Limited, amended the concrete slab pouring methodology so that in essence a continuous supply of concrete was required. Any delay in concrete supply would not only slow down the job but could result in a cold joint or area of poor vibration between pours and this was unacceptable.

Firth has a well-proven Con-E-Co Lo Pro truck mix plant already established on site with a haul distance of about 1km. The plant is load fed aggregate into 40 m^3 of live storage, power supply is from a portable on-site generator, and mains water is available on-site.

The plant was given a complete maintenance check, and a back-up generator, compressor and loader kept on-site. The limiting factor for production was the time to discharge a load into a truck, so drivers were instructed not to waste time getting under or away from the loading point.

Firth's Manukau plant was on stand-by as backup, but was not required.

Two teams split into a day and a night shift, prepared and placed concrete 24 hours a day. Concrete was poured directly from the trucks into place and compacted with powerful pneumatic spud vibrators.

It was levelled using a rotating screed and bull floating, and then given a broom finish and a spray-on curing membrane. A spray-on antivap was used whenever conditions suggested there was a risk of plastic shrinkage cracking.

Concrete Construction in Progress

The initial programme had each team preparing and placing 475 m^3 per shift, but following the earlier success on the runway threshold at R3.3, 630m3 per shift was expected. The actual average daily placement was 1234 m^3, with a 24 hour best of 1,395 m^3, but 60% of this was placed by the night shift because of a stronger team and better conditions. The stronger team was deliberately put on the night shift to maintain morale, quality and progress.

Every night, the night shift set out to beat their previous best and did more and more of the area set aside for the day shift to do so. Their best placement rate was 828 m^3 in 12 hours. At this rate of placement the concrete plant required aggregate deliveries every 13 minutes and cement deliveries every 50 minutes.

The high production rate and starting two days earlier than expected put pressure on Winstones Aggregates and Golden Bay. Fortunately both managed to scramble and save the day. Winstones roused their transport manager out of bed at 2am to drive an extra truck to keep up with demand, and Golden Bay turned their ship around in extra smart time to manage a just-in- time delivery of still warm and much needed cement.

Firth had trialled new 6 m^3 trucks at the plant for the earlier pour only to find that the hydraulic bowl drives units overheated under the demand of rapid turnaround of full loads. For the main pour six 5 m^3 trucks were relied upon while the drive units on the bigger trucks were upgraded. Drivers hot seated the trucks at the change of shifts.

The concrete plant was staffed with two batching staff, a loader operator and a concrete technician continuously during the pour. There were also numerous visits from nervous management, but the on-site team had the job going so smoothly that every one relaxed and started to enjoy it.

Samples of the fresh concrete were taken throughout the construction period to form compression and flexural test specimens for additional production testing. This was undertaken by both Firth Industries and Beca for independent comparison testing.

At 4 days the average flexural strength was 5.5 MPa and the average compressive strength was 42 MPa. This rose to an average flexural strength of 6.3MPa a compressive strength of 56 MPa at 28 days.

The flexural results are shown graphically in Figures 2 and 3, showing the variation in flexural strengths at 4 and 28 days with density.

The average strengths achieved are well in excess of the specifications even at the early four day strength requirement, and of the 132 test measurements only three dropped below the minimum values and in each case repeat tests showed that for the other samples the minimum strengths had been met as well as the average strength required.

Concrete Construction in Progress

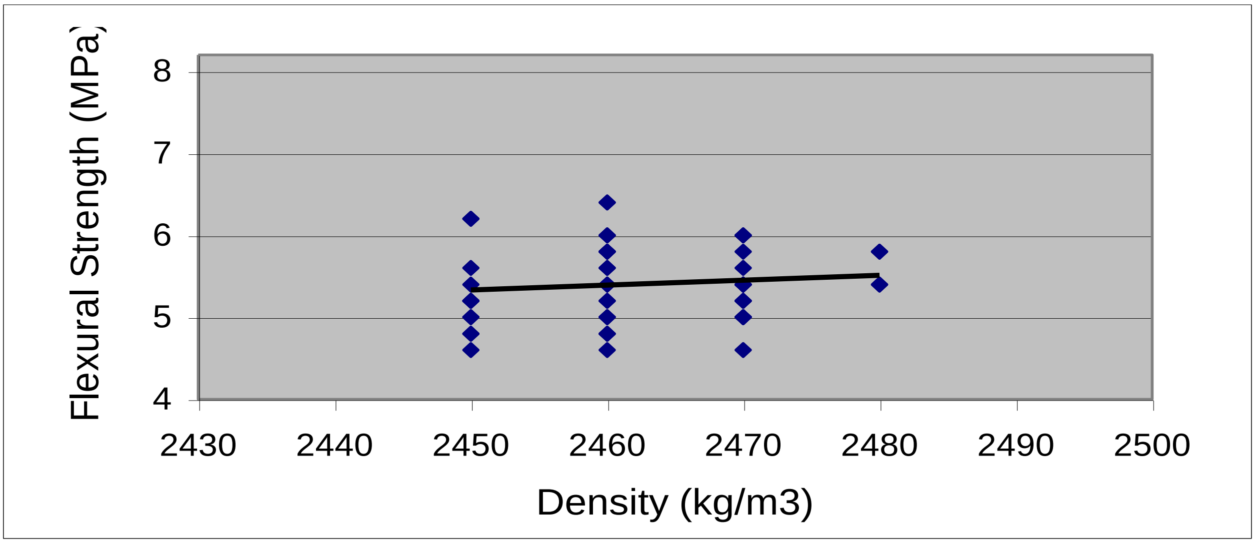


Figure 2 – Variation in Flexural Strength at 4 Days with Density

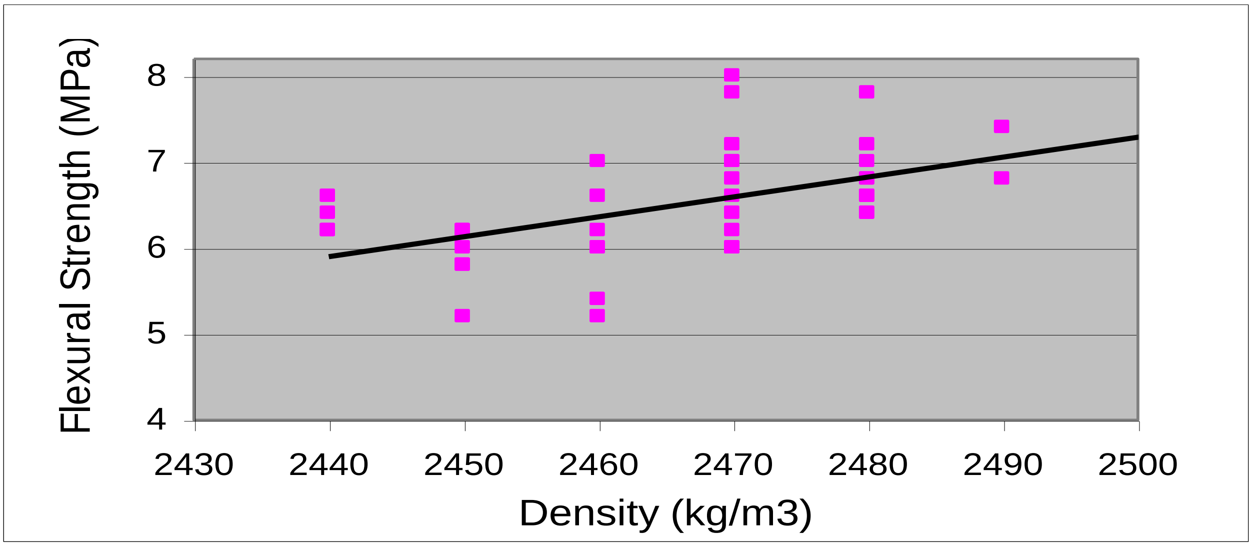


Figure 3 – Variation in Flexural Strength at 28 Days with Density

TECHNICAL INNOVATION

A number of technical innovations were successfully trialled by Beca and Firth during the R3 runway reconstruction.

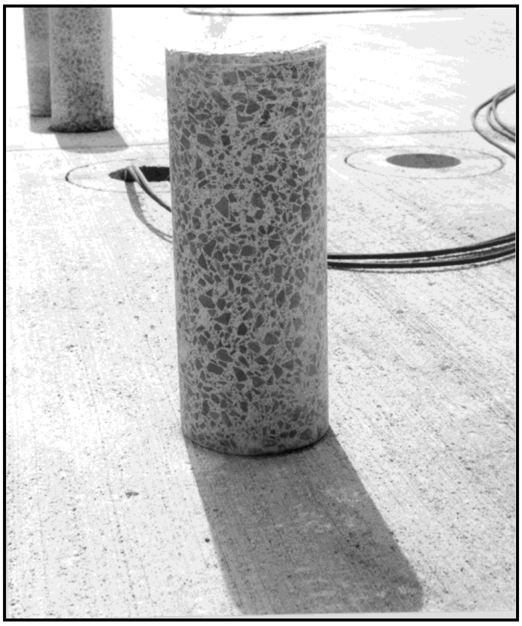
A blast fence was designed and installed on the runway to protect the workers from the effects of jet blast from taxing aircraft nearby. Part of this blast fence could be hydraulically raised and lowered at a moment's notice to provide the required clearances to aircraft. The use of this blast fence minimised the disruption to the workers from aircraft and hence improved the work programme and flow.

Blast Fence in Operation

The use of the large front end loaders fitted with forks to remove concrete slabs in one piece to the waiting dump trucks was also an innovation put forward by the earthworks contractor, Kaipara Earthworks Limited. This replaced the previous method of rock breakers and excavators to remove the concrete slabs in smaller pieces and greatly sped up the removal phase of the project.

Front End Loaders Lifting a Slab

A further innovation to speed up the time of concrete construction was the use of buried light bases instead of conventional light pots for the runway and taxiway lighting. These original light pots take time to set up and also interfere with the concrete delivery trucks. Instead a system of buried junction boxes was developed beneath the base of the concrete slabs carefully positioned and surveyed so that their position was known after the new concrete had been placed. After the concrete had been cured the light positions were resurveyed and holes cored down to the buried box system. This process greatly reduced the time required to pour the new concrete slabs.



Core taken for Light Position

The final innovation involved in the project was the use of careful temperature monitoring of the freshly poured concrete. As the concrete curing would be critical to the re-opening of the runway, a research project was undertaken to measure the rates of strength gain of concrete beams under various temperature curing conditions. The results of the trials were combined with overseas research and provided a fuller understanding of the rate of strength gain of insitu concrete. The theory applied was that insitu concrete in a mass concrete slab develops temperatures of well in excess of the standard 21°C temperature that laboratory samples are tested at and therefore gain strength more rapidly as a result of the higher temperatures. Insitu temperatures were monitored in the concrete pours using buried K probe thermocouples. Based on these temperatures the concrete pavement was assessed to have developed the required flexural strength and the pavement was approved for trafficking after 4 days curing as planned.

SUMMARY

In total, detailed planning was carried out for the R3 runway replacement project for a period of 12 months. All of this time for a project that would take less than one month to complete. In addition, the temporary runway had been planned for a further 12 months and constructed between 2000 and 2001 so all in all 4 years of preparation had gone into this one month long project.

Risks seminars were undertaken to make sure that nothing could go wrong during the project. I's were dotted and T's were crossed as every aspect of the project was checked, rechecked and then rechecked again. The key to project success was to identify the challenges and risks and to determine acceptable solutions. The project ethos developed was *"be prepared – know when, know where, know how, know why!"*

The R3 reconstruction project was completed successfully within 23 days, seven days ahead of programme. That this was possible is testament to all parties involved in this contract from designers, airport operators to contractors and suppliers alike. Motivation of the workers over gruelling 12 hour shifts day and night, day after day was an important aspect of the project.

Both the airport company and the airlines and airport operators were delighted with the project, giving the airport a new lease of life for the R3 section and completing the project without a single hiccup.

Beca and Firth thank Auckland International Airport Limited for their support throughout this project.