Airfield Tactical Training Facility: Pavement Design Summary Report

Ben Whyte, z3337731

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The aim of this project was to produce a detailed design report of an airfield to be used as an Australian Defence Force (ADF) tactical training facility for the recently purchased Alenia C-27J Spartan Battlefield Airlift aircraft. As part of the user requirements the design will provide the necessary facilities, in order to train for remote area evacuations and humanitarian aid missions. My focus; the pavement design includes a suitable runway, taxi-way, parking apron and vehicle access road with supporting civil works for drainage. The pavement design is part of an integrated design process of the Airfield Training Facility undertaken by myself and two other colleagues. The motivation behind the integrated design was to encapsulate the fundamental concepts of Civil Engineering learnt thus far in order to produce a practical solution to a potential need within the ADF. The project did not seek to identify new methods or materials in the design of flexible and rigid pavements, but instead followed current best practice in the industry. In doing so I have personally further developed my understanding in what is involved in the design process in general and more specifically pavement design, construction and maintenance which will be key in my future role as an Airfield Engineer within the Royal Australian Air Force (RAAF) and as an Engineer of the future. In order to maintain a reasonable scope on the project supporting components designed were limited as identified in the project scope later in this report. A simplified project management plan for construction including scope of works, risk analysis, network diagram with critical path and a project timeline is also included in the final detailed design report (DDR), with the network diagram and a description on the process at the end of this summary report.

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1 PLTOFF, School of Engineering & Information Technology. ZEIT4501.

Final Project Summary Report 2013, UNSW@ADFA
IV. The Final Output

A. Runway 15/33 & Taxiway 'Alpha'

B. Parking Apron

C. Vehicle Access Road

D. Airstrip Drainage

V. Project Management

VI. Conclusion

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Nomenclature

ADF Australian Defence Force
ADFP Australian Defence Force Publication
APOD Air Point of Disembarkation
APSEM Airfield Pavement Strength Evaluation Manual
ARC Aerodrome Reference Code
ARFL Aeroplane Reference Field Length
ARI Average Recurrence Interval
ASDA Accelerate-Stop Distance Available
ASTM American Society for Testing and Materials
ATC Air Traffic Control
CASA Civil Aviation Safety Authority
CBR California Bearing Ratio
CDF Cumulative Damage Factor
CRCP Continuously Reinforced Concrete Pavements
CWY Clearway
DDR Detailed Design Report
DEEP Directorate of Estate Engineering Policy
DSL Design Subgrade Level
FAA Federal Aviation Administration
$f_c$ Concrete compressive strength
$f_{cd}$ Concrete Design Characteristic Flexural Strength
FOD Foreign Object Damage
HMA Hot Mix Asphalt
IAW In Accordance With
ICAO International Civil Aviation Organisation
IFD Intensity Frequency Duration
JRCP Jointed Reinforced Concrete Pavements
LDA Landing Distance Available
L.L. Liquid Limit
M.C. Moisture Content
MLG Main Landing Gear
MOS Manual of Standards
MTOW Maximum Take-Off Weight
NATA National Association of Testing Authorities
NPA Non-precision Approach
P/C Pass-to-coverage ratio
PCC Portland Cement Concrete
PCP Jointed Plain Concrete Pavements
PI Plasticity Index
P/TC Pass-to-traffic Cycle
RAAF Royal Australian Air Force
SFRC Steel Fibre Reinforced Concrete Pavements
SOW Scope of Works
SSR Scoping Study Report
STOL Short Take-Off and Landing
I. Introduction

The design of the tactical training facility was adapted from a recently completed RAAF Air Point of Disembarkation (APOD) project in Amberley, west of Brisbane. The APOD had no need for an actual runway pavement as aircraft don’t fly in but are simply static training aides, and accommodation blocks have been built to house personnel during long term training and simulation exercises. Using the same plot of land, the purpose of the facility was adapted to include the need for an operational runway and support infrastructure necessary to house and complete minor maintenance for up to six C-27J Spartan Aircraft as well as process cargo and passengers in a tactical environment without the need of an accommodation block. Several assumptions were made during the design process where relevant information was not available, however the reason for using an existing project was to use as much real data available as practicable. It was assumed that although the plot of land is the same, no interaction with the neighboring RAAF base Amberley will be taken into consideration.

This report will provide detail into the scope of the project, as well as a summary on the steps involved in the design process of each pavement structure. Drainage is a major component of all pavement design and as such a basic design including calculations based on hydrology, specifications, schematics, and layouts of the drainage system will be included in this report.

The purpose of the integrated design project was to gain further understanding in design processes within the Civil Engineering industry. It was an opportunity to develop decision making skills, based on engineering judgment. Current best practices were utilized throughout the design process and carried out in accordance with the relevant Standards with reference paid to existing documentation and procedures.

II. Scope of Project

A. Facility Definition

The first step in the process was to clearly identify the function of the facility being designed as part of the Integrated Design group and therefore the project definition. As the project was given to us as an existing facility, it was necessary to decide exactly what we were designing and how it was different from the original APOD. Once the purpose was clearly defined, the user requirements were able to be established and structures required were identified. It was then decided that as the Airfield Engineer of the team, I would focus on the pavements for the facility.

B. Design Traffic

One major determinant in the adapted APOD’s design specifications and layout is of course the type of aircraft it is being designed for. The facility was designed for the recently purchased C-27J Spartan Aircraft (referred to hereafter as the Spartan). The Spartan is a medium sized military transport aircraft and has short take-off and landing (STOL) capabilities. The Royal Australian Air Force (RAAF) has recently purchased ten of the aircraft in order to replace the recently retired A4 DHC-4 Caribou. The specifications of the Spartan of particular interest are as follows:

- Wingspan: 28.7 m
- Length: 22.7 m
- Tail height: 9.65 m
- Maximum take-off weight (MTOW): 31 800 kg
- Typical tyre pressure: 750 kPa
- Maximum landing weight: 30 500 kg
- Fuel capacity: 12 320 L
- Tactical take-off ground run: 580 m
- Troop Transport: Up to 60 passengers
- Medevac: 36 stretchers + 6 medical attendants

2 Conrad Gargett Architecture, 2011
C. Structures to Be Designed

In order to gain a well-rounded understanding of pavement properties and design, the intention was to include both flexible and rigid pavements in the structures to be designed. It became apparent during the research that this would be the case simply by following the international standards and best practices. On top of this, thorough investigation into different examples of each type of pavement was essential in order to gain an appreciation for the different uses for the many options available. The resulting structures are as follows:

- Runway 15/33 – a sealed flexible pavement
- Taxiway ‘Alpha’ – a sealed flexible pavement
- Parking apron – A jointed plain concrete pavement (PCP)
- Vehicle access road – a flexible pavement as a sprayed seal surfaced unbound granular pavement
- Basic open channel flow airstrip drainage

D. Project Deliverable

Once the structures to be designed were agreed upon, the design itself could start. The final deliverable however, was something of a living document. The detailed design report (DDR) being produced as the project deliverable, has been written from the contracted designer’s point of view to the client, being defence. While it does give steps into what has been designed for construction and the reasons behind the design choices, it is somewhat like a project specification. The engineering process and calculations involved are not foremost in the DDR and the decision was therefore made to include the workings and processes as an appendix to the report. The schematics, diagrams and charts are also supplied as an appendix to the DDR.

III. The Design Process

The decision was made to use the site of the existing APOD facility in Amberley for the modified facility. This decision was made in order to reduce the number of assumptions that would need to be made such as available area, drainage conditions, geotechnical conditions, etc. and make the project as real as possible. The size of the site is very small and the layout became based solely on how the Civil Aviation Safety Authority (CASA) and Federal Aviation Administration (FAA) standards of airstrip size requirements would fit. With the runway direction pre-determined by the local prevailing winds, combined with the known location of the Bremer River in the North-Eastern corner, there was only one way the facility could actually fit into the site which is shown below in Figure 1. Several standards, design guides and manuals were used in the design process, including the International Civil Aviation Organisation (ICAO), United States Federal Aviation Administration (FAA), Australian Civil Aviation Safety Authority (CASA), and Australian Defence Force Publication (ADFP-602).

The geometric design involved close study of the CASA Manual of Standards Part 139 - Aerodromes (MOS-139) and relating several key aircraft parameters with aerodrome requirements. This determined the Aerodrome Reference Code (ARC) ‘1C’ for the Spartan as shown below in Table 1. The dimensions of the runway, taxiway and parking apron were then determined in accordance with the standards.

<table>
<thead>
<tr>
<th>Aerodrome Reference Code</th>
<th>Code element 1</th>
<th>Code element 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Code number</td>
<td>Aeroplane reference field length</td>
<td>Code letter</td>
</tr>
<tr>
<td>1</td>
<td>Less than 800 m</td>
<td>A</td>
</tr>
<tr>
<td>2</td>
<td>800 m up to but not including 1200 m</td>
<td>B</td>
</tr>
<tr>
<td>3</td>
<td>1200 m up to but not including 1800 m</td>
<td>C</td>
</tr>
<tr>
<td>4</td>
<td>1800 m and over</td>
<td>D</td>
</tr>
<tr>
<td></td>
<td></td>
<td>E</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F</td>
</tr>
</tbody>
</table>
According to the National Crushed Stone Association the process for all aircraft pavement design can be broken down into five steps as follows:

A. Evaluate the soil support
B. Estimate the aircraft loads
C. Select the required pavement thickness
D. Check the design adequacy with respect to severe climatic regions
E. Consider other pavement requirements

A. Evaluate Soil Support

Given the location and basic layout of the airfield facility, the first step in the runway design process was to evaluate the soil support or sub-grade to be used. The purpose of the sub-grade is to provide uniform support for the pavement and carry the stresses transmitted through the pavement structure from aircraft loadings. The condition of the sub-grade is the principle factor in governing the flexible pavement thickness and determining the need for additional supporting layers. The types of materials that make up the sub-grade also establish the need for subsurface drainage layers. The California Bearing Ratio (CBR) Test provides a dependable index of soil load bearing capacity. Figure 2 details various soil descriptions and their CBR strength values. If complete CBR testing isn’t practical existing data for the area may be used or approximate correlations from figure 2 may be applied.
In order to determine the existing soil conditions on site, the group requested the geotechnical report that was completed for the original APOD from Cardno Bowler who performed the investigation. It can be seen from table 2, that the existing subgrade is a highly expansive reactive soil with a liquid limit in excess of 70%, a plasticity index greater than 45 and potential swell of up to 6.5%. It is also a very low strength subgrade with a CBR value of 1.0 as can be seen in table 3. According to the recommendations a subgrade having a California Bearing Ratio (CBR) of 10 or greater is considered essential and can support heavy loads and repetitious loading without excessive deformation. The decision was therefore made to replace the existing subgrade with a select fill material with a design CBR of 10 to a compacted depth of not less than 600 mm below the design subgrade level. Unified Soil Classification System well graded sand to sandy clay can be sourced locally and can be seen above in Figure 2 as an excellent subgrade (USCS: SW – SC).

### Table 2: In-situ Subgrade Atterberg Limits

<table>
<thead>
<tr>
<th>Bore No</th>
<th>Depth (m)</th>
<th>% Sand &amp; Gravel</th>
<th>% Silt &amp; Clay</th>
<th>M.C (%)</th>
<th>L.L. (%)</th>
<th>P.I. (%)</th>
<th>Linear Shrinkage (%)</th>
<th>Shrink Swell (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>0.3-0.8</td>
<td>-</td>
<td>28.7</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3.9</td>
</tr>
<tr>
<td>5</td>
<td>0.2-0.7</td>
<td>-</td>
<td>30.9</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>6.5</td>
</tr>
<tr>
<td>0.5-0.6</td>
<td></td>
<td>2</td>
<td>98</td>
<td>21.5</td>
<td>73</td>
<td>53</td>
<td>21.5</td>
<td>-</td>
</tr>
</tbody>
</table>

### Table 3: In-situ Subgrade CBR Values

<table>
<thead>
<tr>
<th>Location</th>
<th>Depth (m)</th>
<th>CBR (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBR1 East Side</td>
<td>0.2-0.8</td>
<td>1.0</td>
</tr>
<tr>
<td>CBR2 Centre</td>
<td>0.2-0.8</td>
<td>1.0</td>
</tr>
<tr>
<td>CBR3 Far West</td>
<td>0.2-0.8</td>
<td>1.5</td>
</tr>
</tbody>
</table>

### B. Estimate Aircraft Loads

The second step was to estimate the aircraft loads. The fundamental information needed in order to accurately estimate loads was; number of passes of various types of aircraft, the magnitude of the loads, the distribution (channelization) of traffic and the tyre pressures of the critical aircraft using the pavement. It is common practice to design runway pavements for the most critical aircraft (heaviest wheel load) that will normally operate from the airport. With the type of aircraft, the landing gear configuration and magnitude of the loads known, this step became a process of determining the volume of traffic the pavements would be designed for over the design life.

The facility was designed for use by the Alenia C-27J Spartan Battlefield Airlift Aircraft, and while future use of the facility for other aircraft such as the RAAF C-130J Hercules would ideally be considered, the length available for the runway has determined very few heavy aircraft will be able to land on it, and therefore the pavements will not be used for any other purpose unless authorised by the Directorate of Estate Engineering Policy (DEEP), Civil Engineering Section. The maximum number of aircraft movements was forecast by the RAAF and the following assumptions were made to determine the total movements for the design of the aircraft pavements:

- 5% departure annual growth
- Maximum take-off weight for all aircraft movements
- Wander of aircraft wheel paths on runways and shoulders was modelled with a statistically normal distribution used in the pass-to-coverage ratio (P/C)
- 20 year design life for flexible pavements
- 20 year design life for rigid pavements
- Pavement design considers only departures and ignores the arrival traffic due to fuel consumption resulting in significantly lower weight
- FAA has defined a standard traffic cycle (TC) as one take-off and one landing of the same aircraft
- Due to the central taxiway configuration a pass-to-traffic cycle ratio (P/TC) of 2 has been adopted
- 2015 departures based on 8 departures per day, 5 days per week, 50 weeks per year equals 2000 departures

The total number of movements for the flexible aircraft pavements over the first year of 2000 departures was then forecast with a 5% annual growth over 20 years and multiplied by P/TC ratio. When averaged over the 20 year life the pavements are designed for approximately 6615 annual departures. The design traffic for the rigid parking apron included the fuel tanker movements plus the same number of aircraft movements, and was therefore designed for nearly twice the traffic of the flexible aircraft pavements. The fuel tanker design traffic was calculated in accordance with AUSTROADS part 6 for the vehicle access road design.
C. Select Required Pavement Thickness

The next step in the pavement design process was to determine the pavement thickness. In order to do this the CBR value of the materials being used was identified. The thickness required above each layer to prevent shear deformation was then determined. In accordance with best practice, generally a maximum layer thickness of 150mm after compaction was adopted. The total flexible pavement thickness above the sub-grade was then checked against Figure 3. The red dashed line shows an example where a CBR value of 10 is known; the graph is entered from the top to the 10 kip wheel load value curve and across to the left side of the graph to obtain ten inches total design thickness, (one kip = 1000 pounds force). The thickness and composition of the surfacing layer primarily depends on the quality of the base material and on the climate.

D. Climate Design Adequacy

The design was checked for susceptibility to frost damage. Frost susceptibility of soils is largely unrelated to CBR values, rather the amount and character of fines is believed to be most related. Table 4 identifies the frost susceptibility of different soils and their associated percentage of fines. Damage to pavements resulting from frost depends on the presence of frost susceptible soils in the sub-grade, freezing temperatures extending to the sub-grade, and a source of free water to these soils. Except where these conditions exist, design thickness for temperate climates will be suitable.

E. Other Pavement Requirements

In order to be economical, it is theoretically possible to reduce pavement thickness where the loads are light such as shoulders and runway ends. This may result in substantial reduction in material costs for large projects, however due to the size and nature of the APOD project any potential advantages were outweighed by the extra time in calculations and construction and therefore were not considered. In accordance with usual practice for light and medium aircraft, flexible pavements were used for the runway and taxiway in the APOD design. A rigid pavement was designed for the parking apron as mandated by the FAA standards for any areas where an aircraft is regularly parked, maintained or serviced. The apron will also be subject to jet fuel spillage and may require a special seal coat. Portland cement concrete has proven be most suitable in these areas.

F. Drainage Design

The purpose of airfield drainage is to dispose of water which may hinder any activity necessary to the safe and efficient operation of the airfield. It should collect and remove surface water runoff and excess underground water from all areas. There are many sources of data utilized in gathering the required information in order to calculate the amount of water to be drained, such as:

- Topographic maps
- Soil reports
- Determinations of water tables
- Intensity, frequency and duration of rainfall, climate and temperature reports
- and the nature of the area surrounding the site

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3 National Crushed Stone Association, 1973
4 National Crushed Stone Association, 1973
5 Department of Transportation, Federal Aviation Administration, 1970
The water from the APOD drainage system will be carried to the Bremer River to the North-East of the runway. **Figure 4** shows the highest annual flood peaks. Of particular interest is the regularity of flood peaks considered major as indicated by the red line. It can be seen that regardless of the capacity of the drainage system designed the airfield will inevitably flood. The goal was to ensure the system can manage a substantial rain event, allowing safe use of the pavement structures and to minimize damage caused when floods do occur. This was achieved by using hydrology to accurately calculate the runoff to be collected and ultimately disposed of.

**G. Modified APOD Layout**

The layout of the APOD facility is shown in **Figure 5**. The required turnpads at each end of the runway can be seen with the desired wheel path of the turn circle allowing sufficient clearance of the MLG wheels preventing any damage to the shoulder edges. The runway strip surrounds the runway indicating an area to be free of obstacles, the same applies to the taxiway strip surrounding the taxiway. The parking apron has allocated parking for 4 aircraft with minimum 10 m wing tip clearance while still allowing access to the maintenance hangar and terminal hangar. The vehicle access road is shown in yellow to the south-east of the site.

*Figure 5: Modified APOD Layout*

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IV. The Final Output

A. Runway 15/33 & Taxiway 'Alpha'

As previously mentioned all pavements were designed with a 20 year design life. The geometry was determined according to ARC '1C' with a turn pad at each end due to the central taxiway configuration. The length of the runway was calculated by correcting the Spartan's reference field length of 580m for elevation temperature and slope. The ICAO Aerodrome design manual states the reference field length is to be increased by 7% per 300m above sea level, then 1% for every 1°C above standard atmospheric conditions and 10% for every 1% runway slope. The runway length was therefore calculated as $580m \times 1.007 \times 1.2 \times 1.1 = 770m$. The runway strip length is then an additional 60m each end.

The pavement design for both the runway and taxiway is essentially the same other than the width and is shown in Figure 5 with a total thickness of 390mm. The structure is broken down into 135mm crushed aggregate subbase placed and compacted to FAA Spec P-209, with a 150mm layer P-403 stabilized flexible course of crushed aggregate combined with a bituminous material, and a 105mm layer of P-401 Hot Mix Asphalt (HMA) wearing course. Figure 5 is set to scale with the vertical scale exaggerated at 1:5 in order highlight the individual layers and display the two-way cross-fall.

![Figure 5: Runway 15/33 & Taxiway 'Alpha' Pavement Structure](image)

B. Parking Apron

The United Facilities Criteria 'Pavement Design for Airfields' stipulates rigid pavements must be used wherever an aircraft is regularly parked, maintained or serviced, and as such the parking apron is a rigid pavement. Jointed plane concrete pavement (PCP) is the most widely used and was deemed suitable for the APOD facility. The design utilized the concrete flexural strength (4.8 MPa from FAA Standards), foundation modulus (10 x CBR = 100 MPa) and traffic loading as the key inputs. Transverse contraction joints and longitudinal construction joints were spaced to form 6m x 6m slabs. The longitudinal construction joints as well as regularly spaced transverse construction joints were designed as dowelled butt joints as detailed in Figure 6 to provide load transfer and maintain slab alignment. The apron dimensions of 96m x 132m allows sufficient space for 4 aircraft to be parked with the required 10m wing tip clearance prescribed by the CASA MOS-139 for free moving parking, while still providing access to the maintenance and terminal hangars. Expansion joints are utilized at the interface with the hangars also as detailed in Figure 6.

![Figure 6: PCP Joints](image)

C. Vehicle Access Road

The main process involved with the design of the vehicle access road was the calculation of the design traffic. The use of a sealed flexible pavement was deemed most suitable in order to reduce the risk of foreign object damage (FOD). From the specification of a suitable refueling tanker and number of aircraft traffic cycles the design equivalent standard axles (DESA) and volume of traffic was calculated in accordance with the AUSTROADS process. The pavement was then designed using both an empirical method for sprayed seal surfaced unbound granular pavement, and a mechanistic design procedure for an asphalt pavement containing cemented material. An analysis was then performed in the AUSTROADS program CIRCLY in order to identify
the critical strains for the different modes of failure. The most economical design was considered to be the sprayed seal pavement.

D. Airstrip Drainage

The drainage design involved the identification of the required design parameters; frequency/average recurrence interval (ARI), geometry, slope, lining, freeboard & shear stress. The discharge frequency of 10 years was selected in accordance with FAA Surface Drainage Design, and a simple trapezoidal geometry open channel considered a cost effective approach for the nature of the facility. The slope of the channel is the same as the airstrip at 1% toward the Bremer River which not only negates the need for a deep channel but also negated the need for drainage culverts across the runway. The natural grasses and vegetation of the area, if maintained to a height of not more than 0.2m were considered suitable for the channel lining, and a freeboard of 0.15m considered adequate due to the relatively low consequence of overflow. Shear stress values were taken directly from FAA Surface Drainage Design and 0.03 kPa was identified for class D vegetation lining.

In order to design the geometry of the channel, the peak flow rate was calculated with the use of design Intensity Frequency Duration (IFD) curves and equated to the flow rate of an open channel drain using Manning's equation. A suitable side slope of 1V:3H was also selected so as not to exceed the angle of repose of the soil. The IFD curves are shown below in Figure 7 with the channel design shown in Figure 8.

![Figure 7: Bremer River IFD Curves](image)

![Figure 8: Open Channel Drainage Design](image)
V. Project Management

Project management tasks were completed as an integrated design team. The project construction will be completed by 21 Construction Squadron reducing costs while providing useful training and experience for all involved. The project timeline was created by breaking down each milestone task into associated sub-tasks and identifying what order structures needed to be constructed before subsequent tasks could begin. Approximate timings were estimated based on the processes involved, plant available as well as information available from relevant sources. From the overall project Gantt chart created on Microsoft Project, the critical path was formed as mentioned above by identifying the order in which milestone tasks were to be completed. It can be seen by the Network diagram shown that a major project milestone is completion of the Parking Apron and in particular the 28 day cure time of the concrete. This task must be completed before construction on the Hangars can take place as the plant used will utilize the apron surface for some construction works. Further breakdown of each task shown into sub-tasks can be seen on the final detailed design report submission along with material costing’s.

VI. Conclusion

The integrated design process was immensely beneficial in further developing some of the fundamental principles learnt throughout the Civil Engineering degree. Through the course of cross-checking each other’s designs, the team gained a better understanding in the procedure of designing several types of structures utilizing degree courses such as; Statics, Construct Survey and Transport, Soil Mechanics and Engineering Geology, Geotechnical Engineering, Project Management, Steel Design, Concrete Structures, Structural Analysis and Foundation and Pavement Engineering. As well as gaining a better understanding in the design procedure, by investigating each other’s reasoning and methodology behind the design process, issues of working in an Engineering team environment and project management have also been further developed. The realistic nature of the project and the information available to us added further benefit in deducing user requirements of the key stakeholders, as much of the data is prescribed rather than assumed. The project has been an invaluable capstone to my learning path and will be particularly pertinent to my nest role in just 3 months time as the sole Airfield Engineer in my new unit; 381 Expeditionary Combat Support Squadron, where tactical airstrips will be paramount.
VII. Reference List


