REHABILITATION OF RUNWAYS, TAXIWAYS AND ASSOCIATED AIRSIDE INFRASTRUCTURE TO ICAO STANDARDS AT THE EAST LONDON AIRPORT – A PROJECT NARRATIVE

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The East London airport is, in terms of passenger movements, the second largest "regional airport" in South Africa and is the origin and destination of travellers and freight to and from East London and further, via road, the north eastern portion of the Eastern Cape Province.

Due to the fact that the area has four (4) distinct prevailing wind directions, which can be gale force at times, the airport has two runways i.e. a "main" runway and a "secondary" runway which are aligned at an angle of approximately 50 degrees to each other. The runways were originally constructed between 1953 and 1961 and they have received various re-surfacing and rehabilitation actions in the intervening time.

At some point, both the runways were overlaid with a "porous" asphalt wearing course. In 2003, the centre portion of the main runway was inlaid with modified asphalt whilst the centre portion of the secondary runway received an application of bituminous sealing agent. Airports Company South Africa (ACSA), being aware (from the results of the annual Pavement Management System reports) of continuing surface degradation, initiated projects in 2009 and 2010 to address surfacing distress – mainly severe ravelling of the porous asphalt on both runways which presented a Foreign Object Debris / Damage (F.O.D.) risk. These projects were undertaken using the "mill and fill" method.

The above interventions would have been adequate to ensure 3-4 years of serviceable life for the two runways but, notwithstanding, ACSA initiated a project that would involve the rehabilitation of not only the two runways, but also the taxiways, Runway End Safety Areas (RESA's) / side strips and other airside infrastructure. All airside infrastructures was to be designed and constructed to the International Civil Aviation Organisation (ICAO) Annexure 14 standards.

The project was awarded to GIBB (Pty) Ltd in February 2011, with a brief to undertake detailed assessments of the airside facilities, identify requisite rehabilitation / upgrading measures, compile construction contract documentation, contractor procurement and provide construction management.

The design process started in March 2011, with a contractor being appointed in December of the same year. Construction commenced in January / February 2012 and was completed in June 2013.

The works comprise, inter alia, structural and geometric upgrades to the runways and taxiways using asphalt inlays and overlays, with friction courses to both runways using bitumen rubber semi open graded asphalt construction (+/- 270,000 sq. metres), earth and layerworks for the construction of four new RESA's and geometric improvements to the various side strips (800,000 sq. metres), rehabilitation of the airside service roads and requisite electrical works.

As it was essential that "normal" airport operations were maintained, the entire construction was undertaken at night with the requirement that all facilities were available for use by 05:00 the next day.

This is the single largest infrastructure project ever undertaken at the East London Airport, with a construction cost of R190 Million (A$ 20 Million).

This Paper discusses the structural and geometric design rationale, to ICAO standards, the contractor procurement process, technical issues (particularly with respect to the various asphalt mix designs), risk mitigation, project constraints and presents an account of the 17 month construction phase – including valuable lessons learnt.

INTRODUCTION AND PROJECT BACKGROUND

The East London Airport, in terms of passenger movements, is the second largest "domestic" airport in South Africa and is the origin and destination of travellers and freight to and from East London and, further the north eastern portion of the Eastern Cape Province.

Due to the fact that the area has four (4) distinct prevailing winds, which are gale force at times, the airport has two runways i.e. a "main" runway (11/29) and a "secondary" runway (06/24) which are aligned at an angle of approximately 50 degrees to each other.

The main runway was originally constructed in 1953, with the secondary runway being opened in 1961. An aerial view of the airport is presented in Figure 1 below, whilst an annotated layout is given in Figure 2 overleaf.

Figure 1 : Arial View of the East London Airport

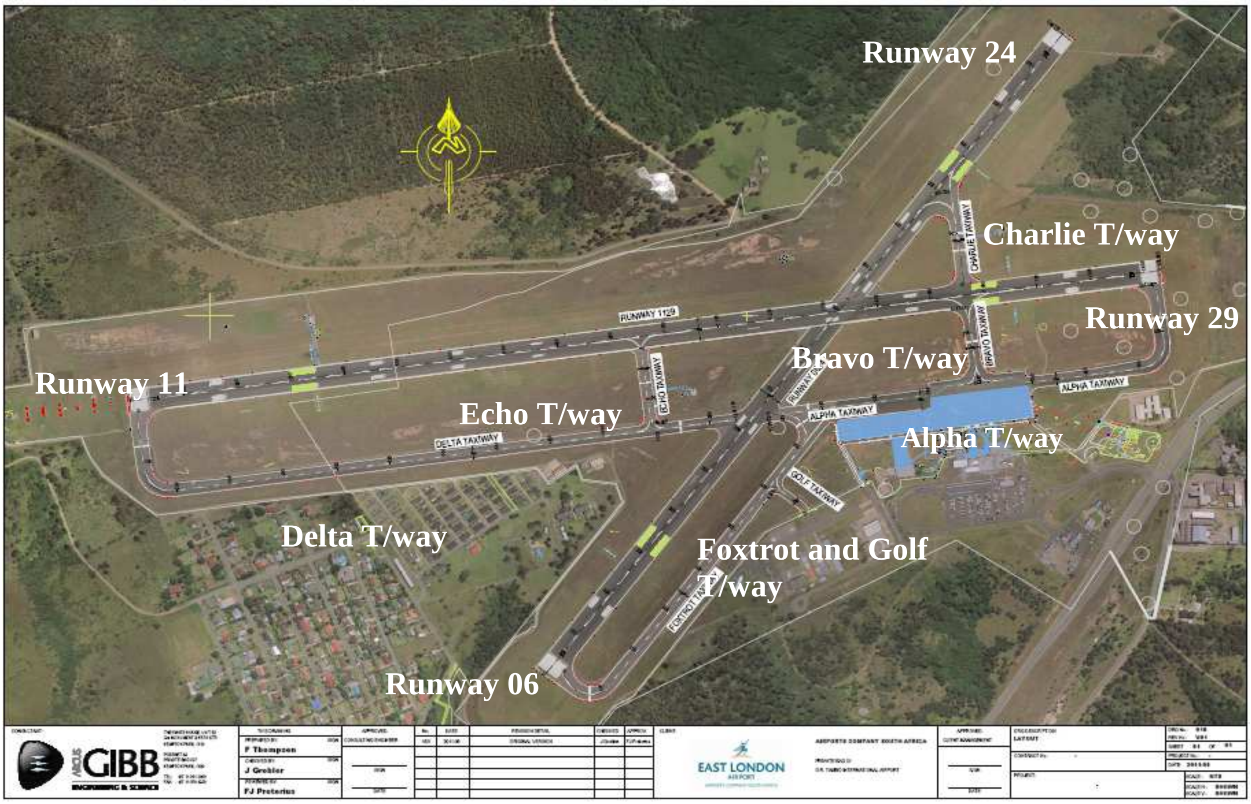

Figure 2 : Runway and Taxiway Configuration

Runway 11/29 is 1,940 metres long, whilst runway 06/24 measures 1,590 metres in length, with both runways being 45 metres wide. In terms of the taxiways, Alpha / Delta are the most heavily used taxiways as they service the main runway. These taxiways, when added together, measure 2195 metres in length with a paved width of 30 metres. The combined length of the remaining four (4) taxiways is 1314 metres with an average width of 30 metres each. The combined length of the runways and taxiways rehabilitated under this project is 7039 metres with an area of approximately 270,000 square metres.

Various pavement rehabilitation / preservation projects have been undertaken on the runways and taxiways since their construction, with the most recent (prior to this project) being the remedial intervention on the shoulders of Runway 06/24 in 2009 / 2010. This project entailed the repair, by the "mill and fill" method, of oxidized / brittle asphalt, with the aim of incorporating the work into the new pavement structure created by this project.

The 2009/2010 interventions would have been adequate to provide 3-4 years of serviceable life for the two runways but, this notwithstanding, ACSA initiated a project that would involve the rehabilitation of not only the two runways, but also the taxiways. Runway End Safety Areas (RESA's) / side strips and other airside infrastructure.) to ICAO Annexure 14 recommended standards. The project was awarded to Consulting Engineers, GIBB (Pty) Ltd, in February 2011 who were tasked with providing a design solution by August 2011 with Tender Documentation being required by November 2011 and Contractor procurement by December of the same year – the latter to enable construction to commence in early January 2012.

PROJECT BRIEF

The ACSA Brief to the Consulting Engineers was to produce a design strategy that would provide a minimum of 15 years serviceable life for the runways and taxiways and, further, create RESA's and side strips to Annexure 14 recommended standards. The design and tender stage tasks undertaken were, inter alia, as follows:

- Assessment of the structural condition of the runways and taxiways.
- Assessment of the geometric compliance of the runways and taxiways
- Assessment of Runway “functional” items, i.e. Riding Quality and Skid Resistance.
- Assessment of the structural bearing capacity of the runway strips and runway end safety areas (RESA)
- Assessment of geometric compliance of the strips and RESA
- Assessment of existing drainage facilities (both surface and sub-surface)
- Assessment of ancillary aspects such as existing electrical installations and new infrastructure requirements
- Risk identification / assessment and mitigation.
- Pavement and geometric design for runways and taxiways
- Structural and geometric design for RESA’s and strips
- Calculation of quantities
- Compilation of design report
- Compilation of tender documentation and tender drawings
- Compilation of tender evaluation report

As already discussed, the entire design and tender stage for the project was to be concluded by December 2011, i.e. within a 10 month period

DESIGN METHODOLOGY

Assessment Stage

The assessment stage of the design process was initiated in March 2011 with the following tasks being undertaken:

- Obtain and analyse available data
- Detailed visual assessment of the runways and taxiways
- Tacheometric survey of the entire “Airside” area
- Falling Weight Deflectometer (FWD) and Friction Testing
- Materials investigation in the runways and taxiways (asphalt cores, permeability testing, test pits, sampling and materials testing)
- Materials investigation in the RESA’s and side strips (test pits, sampling, materials testing and DCP tests)
- Risk Assessment

Available Data

The assessment of available data included the collation of historical aircraft movements, “As-Built” data, electrical and other services location information etc.

Visual Assessment

The visual assessment data was used to identify the mechanisms of distress and also to identify areas where intrusive testing should be more concentrated. Figures 3 to 6, on the following pages, present examples of the visual assessment sheets.

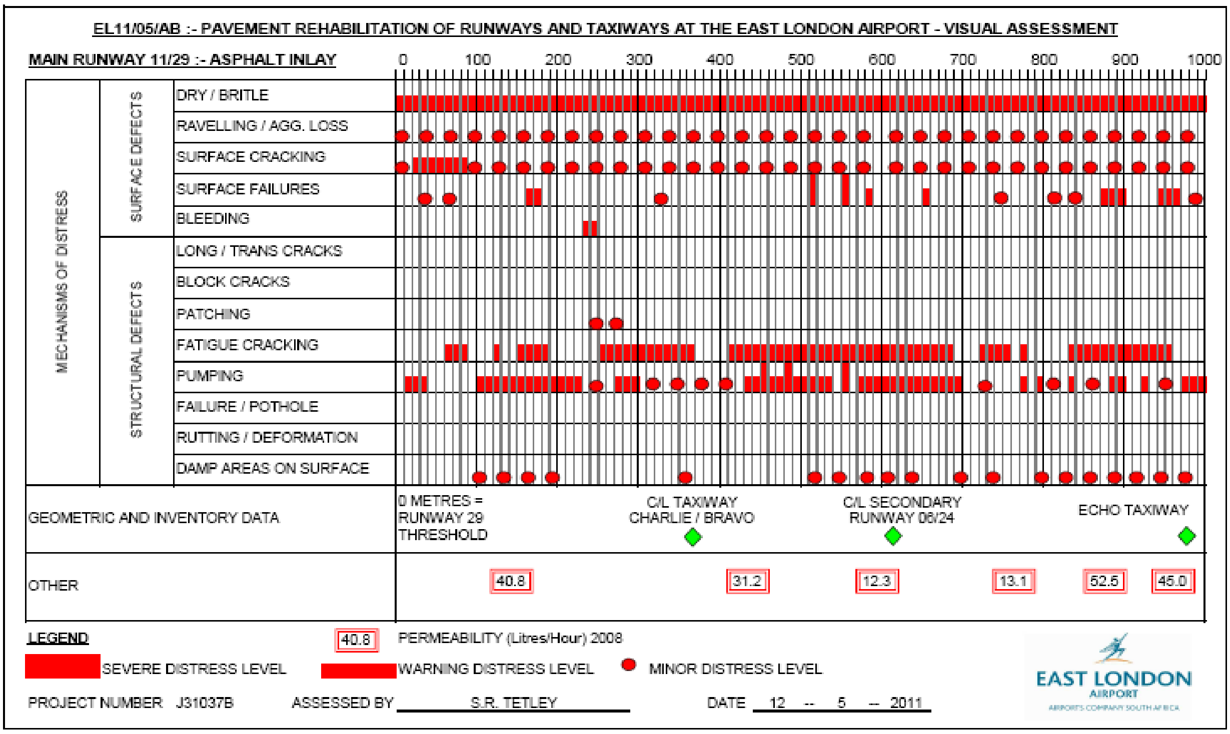

Figure 3 : Visual Assessment Sheet – Runway 11/29 Centre Section

The asphalt on the middle portion of 11/29 was placed circa 2003, as can be seen from the Figure 3, the main mechanisms of distress on this critical area were aged binder (Dry/Brittle) and warning level fatigue cracking with associated pumping of fines. Marvel permeability testing was also carried out and, as may be observed, the results were also a cause for concern.

The shoulders of the main runway consisted of open textured "popcorn" asphalt which was found to be almost completely devoid of any active bituminous binder, this is illustrated by the severe rating of binder condition, ravelling and surface cracking on the assessment sheet for the shoulders of 11/29.

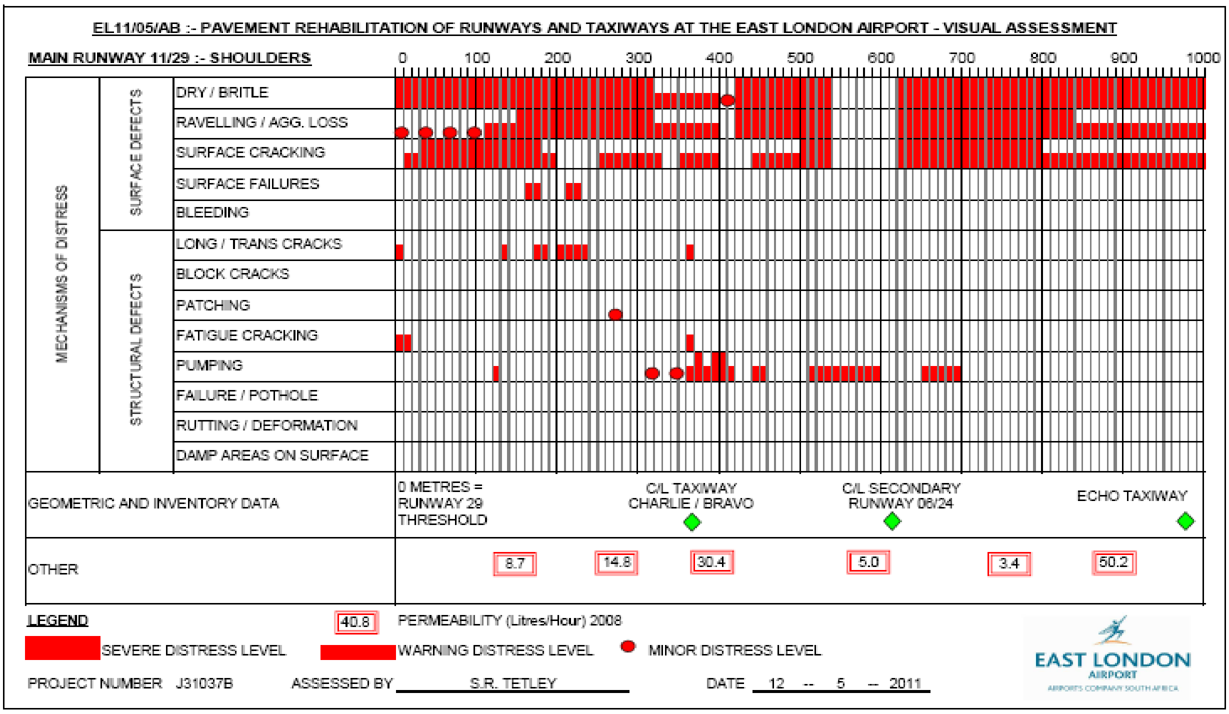

Figure 4 : Visual Assessment Sheet – Runway 11/29 Shoulders

Distress on runway 06/24 was limited to the centre, "keel" portion of the runway 06/24, this as the shoulders were repaired with a "mill and fill" intervention in 2010. Figure 5, below, presents the findings of the visual assessment for runway 06/24 between the threshold of 06 and +1000 metres.

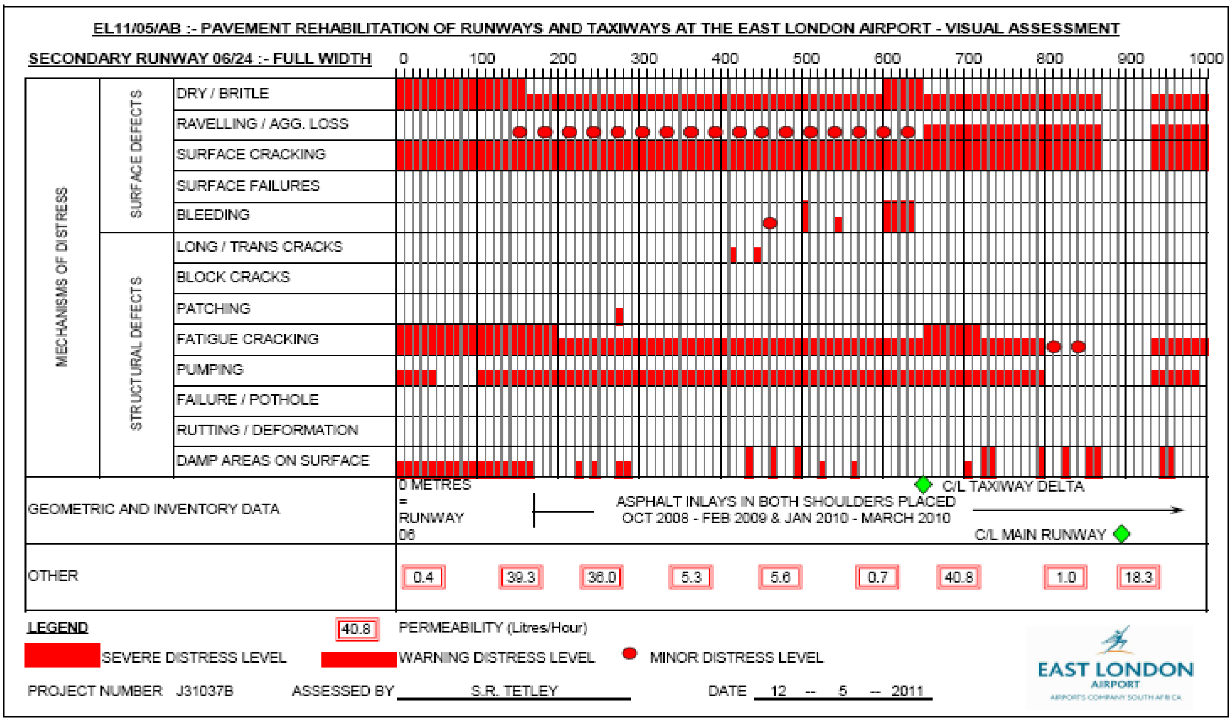

Figure 5 : Visual Assessment Sheet – Runway 06/24 Full Width

As may be observed from Figure 5, the centre portion of the runway was exhibiting severe surface cracking, brittle binder, fatigue cracking and pumping. Permeability results which, whilst generally better than found on runway 11/29, were also not good.

The taxiways were found to be in varying stages of deterioration, with Alpha taxiway being in the worst condition as illustrated in Figure 6

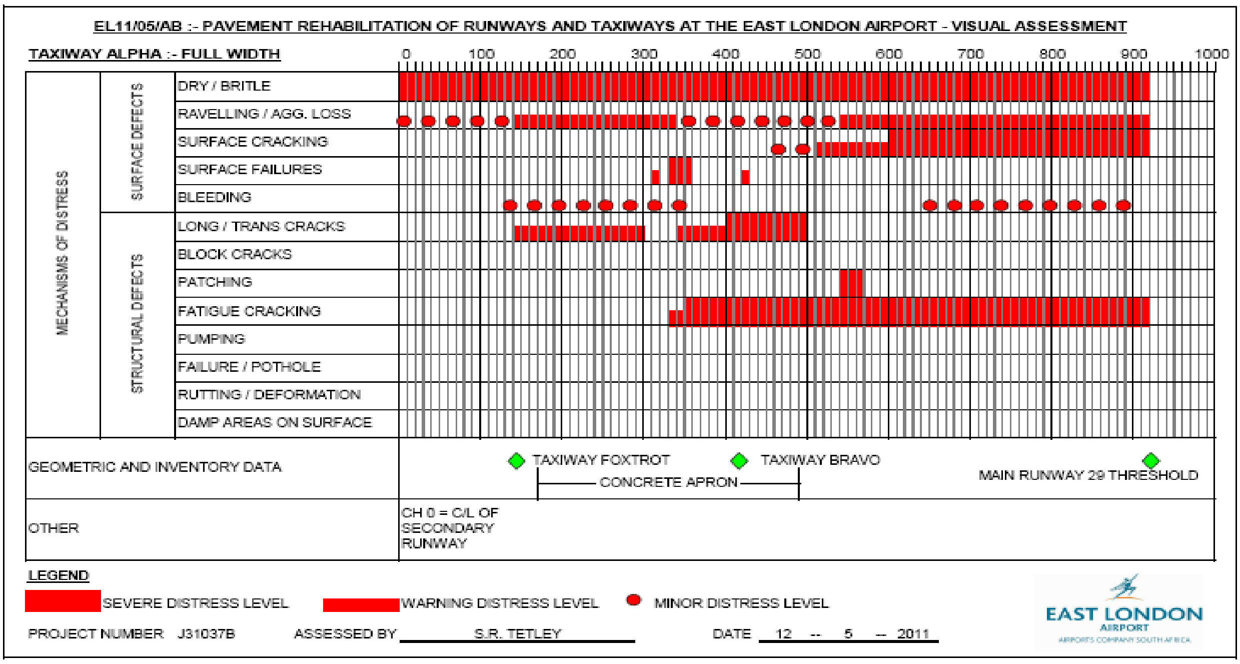

Figure 6 : Visual Assessment Sheet – Alpha Taxiway

Ground Survey

In order to undertake the geometric design of the runways, taxiways, RESA and side strips, a detailed tacheometric ground survey of the "airside" was undertaken. The extent and detail of this survey is illustrated in Figure 7

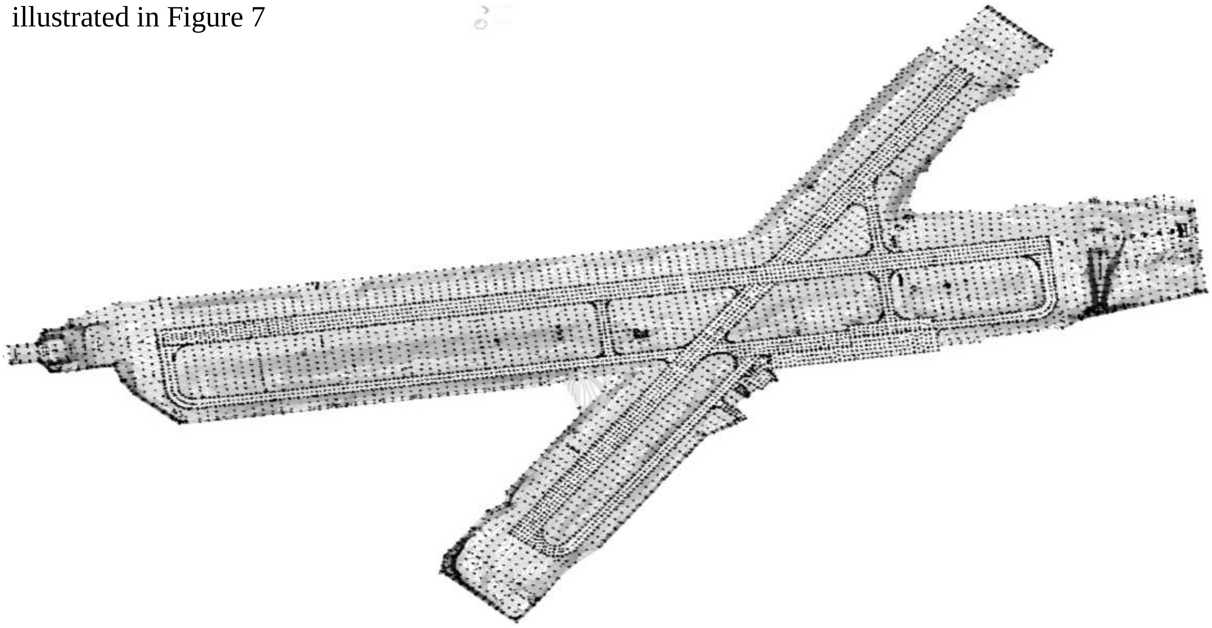

Figure 7 : Tacheometric Survey Digital Terrain Model (DTM)

The DTM was loaded into MX Road design software from which the final geometric alignment for the runways, taxiways RESA's and strips was generated.

FWD and Friction Testing

So as to establish functional capabilities of the runways and taxiways, falling weight deflectometer (FWD) testing, together with friction testing was undertaken.

FWD testing was carried out using a 120kN load, The measurements were taken on the runways at 20m intervals at 3m left and right of centre line and at 80m intervals for 8m and 20m each side of the centre line.

On the taxiways, measurements were taken on the centreline and at 3m left and right offset with a spacing of 20m. In total, 750 individual points were tested with the results being used for the back calculation of layer moduli in the subsequent mechanistic pavement design process.

Friction testing was carried out during August 2011 using the Griptester apparatus. The results of this testing are illustrated in Figure 8 below

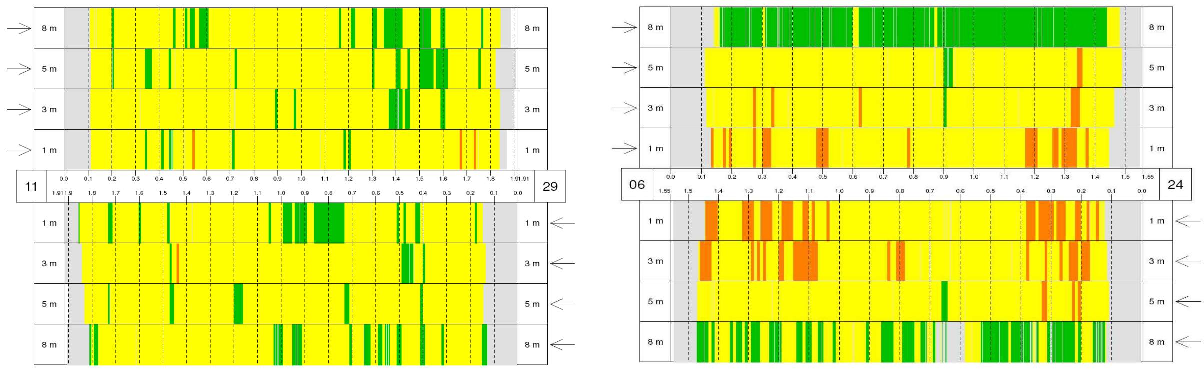

Figure 8 : Friction Testing Results Runway 11/29 (Left) and Runway 06/24 (Right)

Figure 8 indicates that friction levels, prior to the rehabilitation, were predominantly between “design” and “maintenance” levels (yellow) with areas between “maintenance” and “minimum” values (orange)

Materials Investigation

Intrusive sampling and testing of the runway and taxiway pavement structures and in-situ materials in the RESA’s and side strips was carried out to determine layer thickness (particularly important on the various pavement structures) and material type/characteristics and quality. To assess in-situ bearing capacity, Dynamic Cone Penetrometer penetrations were inserted at all test pit locations, with cores being extracted from the runways and taxiways to assess existing asphalt properties. The locations of the testing are presented in Figure 9

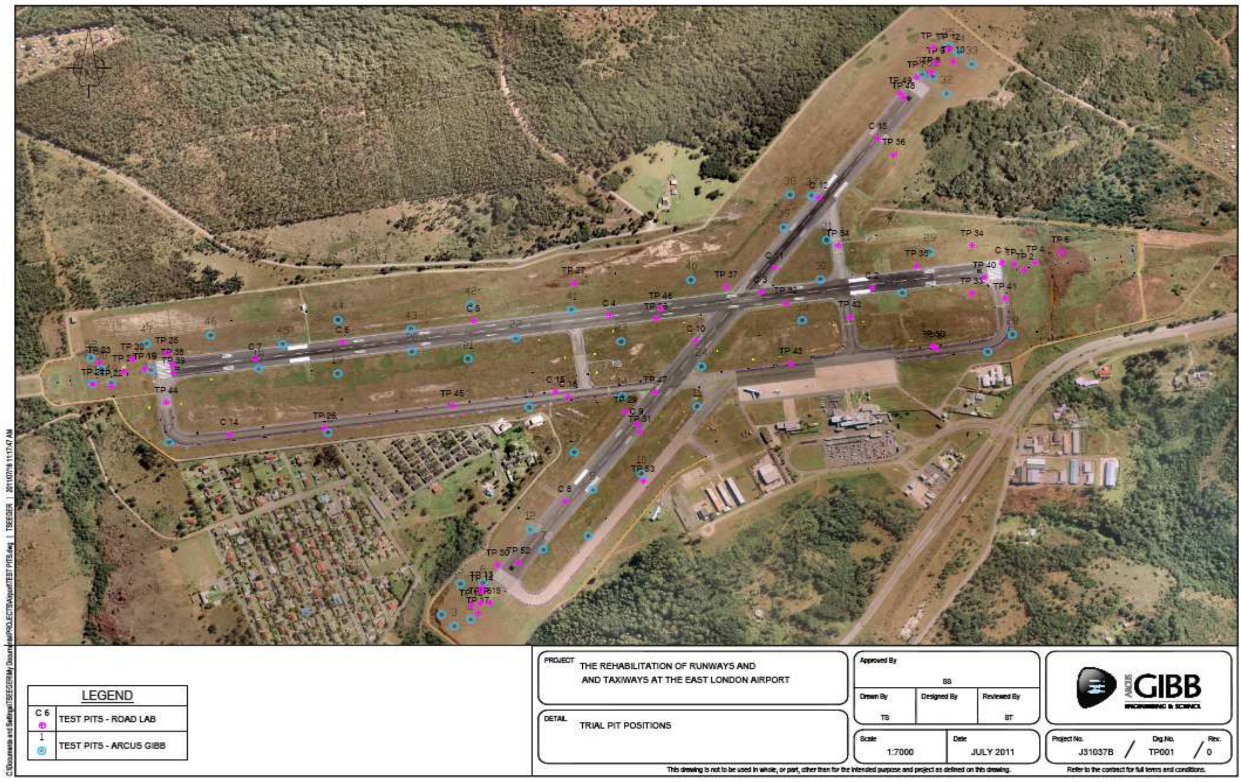

Figure 9 : Materials Investigation Sampling and Testing Positions

A summary of the more important test results for the runways and taxiways is given in Tables 1(a) to 1(c) below.

Table 1(a) : Material Investigation Test Result Summary – 11/29

	Layer	Thickness	Description	Classification*[1]
Runway 11/29	Surfacing	110-130mm	3 x asphalt layers. Centre portion is an 35mm modified asphalt placed in 2003 and is covered in micro cracking. Shoulder surfacing is open textured highly oxidized / brittle asphalt. Underlying asphalt appears to be previous wearing course(s)	AC/A0
	Base	100-120mm	Crushed stone “macadam” tar treated base	G3
	Subbase	300-320mm	Dense crushed gravel sub-base	G5
	Select S’grade	270-400mm	Medium dense sandy gravel	G6

Note *[1] As per Draft TRH4, Pretoria, South Africa. 1996

Table 1(b) : Material Investigation Test Result Summary – 06/24

	Layer	Thickness	Description	Classification*[1]
Runway 11/29	Surfacing	100-110mm	2 x asphalt layers. Centre portion is 45mm open textured asphalt with a modified bituminous sealant applied circa 2003. Shoulder surfacing is 50-70mm continuously graded asphalt placed in 2010. Underlying asphalt is previous wearing course	AC/A0
	Base	90-110mm	Crushed stone "macadam" tar treated base	G3
	Subbase	200-240mm	Dense crushed gravel sub-base	G5
	Select S'grade	400-490mm	Medium dense sandy gravel	G6

Table 1(c) : Material Investigation Test Result Summary – Taxiways

	Layer	Thickness	Description	Classification*[1]
Runway 11/29	Surfacing	100-110mm	2 x asphalt layers. Upper 40-50mm is highly oxidised with fatigue cracking. Underlying asphalt is previous continuously graded asphalt surfacing	AC
	Base	130-180mm	Crushed stone "macadam" base – lightly stabilised	G3
	Subbase	130-180mm	Dense crushed gravel sub-base – lightly stabilised	G4
	Select S'grade	360-400mm	Medium dense fine sandy gravel – lightly stabilised	G6

In terms of ICAO recommendations, the surface of the RESA and strips must be constructed in such a manner to prevent the nose wheel of the aircraft collapsing. The surface must provide "drag" to an aircraft and below the surface, and have sufficient bearing capacity to prevent the nose wheel penetrating more than 150mm. In order to meet these needs, the upper 150mm of the RESA's and strips is constructed from a comparatively low strength material to facilitate deceleration of the aircraft. The layer below this needs to prevent the nose wheel from sinking further and a bearing capacity, in terms of California Bearing Ratio (CBR), of 15-20 is recommended Table(s) 1(d) and (e) present a summary of the test results obtained

Table 1(d) : Material Investigation Test Result Summary – RESA's

	In-Situ Density	CBR @ 90% Mod. AASHTO	CBR @ 95% Mod.	DCP Equiv. CBR
RESA 11&29	98% Mod. AASHTO	32	48	90
	99% Mod. AASHTO	35	59	97
	95% Mod. AASHTO	25	42	48
	96% Mod. AASHTO	6	14	14
	97% Mod. AASHTO	9	16	44
	88% Mod. AASHTO	3	6	34
RESA 06&24	**In-Situ Density**	**CBR @ 90% Mod. AASHTO**	**CBR @ 95% Mod.**	**DCP Equiv. CBR**
	92% Mod. AASHTO	6	14	35
	88% Mod. AASHTO	4	8	9
	84% Mod. AASHTO	5	11	16
	89% Mod. AASHTO	3	6	14
	97% Mod. AASHTO	6	15	23
	88% Mod. AASHTO	5	10	12

As can be observed from the above Table, the bearing capacity of RESA 11 was found to be adequate, whilst the values for RESA's 29; 24 and 06 were found to be lower than the ICAO minimum. In terms of RESA's 06 and 24, the in-situ density was also low at most of the locations tested. The DCP results, whilst obviously returning higher figures than the laboratory derived CBR, did at least corroborate the laboratory test results.

Table 1(e) : Material Investigation Test Result Summary – Side Strips

	In-Situ Density	CBR @ 90% Mod. AASHTO	CBR @ 95% Mod.	DCP Equiv. CBR
11&29	89% Mod. AASHTO	4	9	11
	88% Mod. AASHTO	9	24	20
	85% Mod. AASHTO	7	12	24
	90% Mod. AASHTO	13	23	34
	88% Mod. AASHTO	11	24	48
06&24	**In-Situ Density**	**CBR @ 90% Mod. AASHTO**	**CBR @ 95% Mod.**	**DCP Equiv. CBR**
	91% Mod. AASHTO	7	12	42
	94% Mod. AASHTO	7	10	18
	89% Mod. AASHTO	4	8	12

As for the RESA's, the in-situ density is generally lower than 90% of the Modified AASHTO density, the laboratory results at 95% Mod AASHTO did, however, give reasonable CBR values although the majority were still lower than required. Again, the DCP equivalent CBR's correlated reasonably with the laboratory values, i.e. a position with a good laboratory result generally also gave a good DCP value.

Cores were drilled through the asphalt layers on the runways and taxiways. The initial intention was to undertake laboratory testing for residual binder content, voids etc. This notwithstanding, it was decided, based on the obvious visual evidence of both the cores and the actual surfacing, that the existing asphalt could not be re-used in the new pavement structure and, as such, the cores were only used to classify the asphalt type and establish layer thickness (of the layers below the existing surfacing) for input into the pavement design process.

Figure 10, below, presents some typical photographs of cores extracted from the shoulders of runway 11/29 and the centre portion of runway 06/24.

Figure 10 : Example of Asphalt Cores

From Figure 10, the friable, oxidised, open textured surfacing can clearly be seen, as can the underlying asphalt layers and the large aggregate tar bound macadam base

Risk Assessment

An integral and crucial aspect of the assessment phase of the project was the "Risk Assessment" process. This exercise not only highlighted possible design stage risks, but also identified possible construction risk, the latter being incorporated into the Contract Documentation as additional risk mitigation to the specifications contained in the ACSA "Airside Procedure Manual". The risk register is presented below as Figure 11.

STAGE	RISK	EXPOSURE	MITIGATION MEASURE
DESIGN	EXTENDED PROVISION OF REQUISITE SUB-SERVICES SURVEY, GEOTECH, NON-DESTRUCTIVE TESTING ETC	TIME	APPOINT SUB-SERVICE PROVIDER IN GOOD TIME. CONSTANT SUPERVISION BY A.G. AND PENALTY CLAUSE FOR LATE COMPLETION INCLUDED IN CONTRACT
	REQUIRED REHABILITATION WORK EXCEEDING CAPEX APPROVED CONSTRUCTION BUDGET	FINANCIAL	OPTIMAL PAVEMENT DESIGN IDENTIFICATION. SHOULD AN "OVERSPEND" BE UNAVOIDABLE, THIS MUST BE COMMUNICATED TO ACSA AT THE EARLIEST OPPORTUNITY
	INACCURATE CONSTRUCTION COST ESTIMATE	FINANCIAL	ESTIMATES TO BE BASED ON CURRENT UNIT RATES
	INACCURATE DIRECT AND INDIRECT CASH FLOW FORECASTS	FINANCIAL	TO BE UPDATED ON A MONTHLY BASIS
	NEW RUNWAYS AND TAXIWAYS NOT ACHIEVING THEIR STRUCTURAL DESIGN LIFE	FINANCIAL	DESIGN UNDER THE LEADERSHIP OF RECOGNISED AIRPORT PAVEMENT DESIGN SPECIALIST AND USING BEST PRACTICE DESIGN METHODOLOGY
	SURFACING OR STRUCTURAL FATIGUE TO RUNWAYS AND TAXIWAYS	FINANCIAL / END USER SAFETY	SEE ABOVE
	DESIGN CONSTRUCTION METHODOLOGY IN APPROPRIATE FOR THE REQUIRED CONSTRUCTION PROCESSES - POSSIBLE "LATE" OPENING AFTER NIGHT SHIFT	FINANCIAL / END USER SAFETY	METHODOLOGY TO BE IDENTIFIED THAT WILL NEGATE THE POSSIBILITY OF LATE OPENING. METHODOLOGY TO BE WORKSHOPPED WITH THE RELEVANT PARTIES
	INSUFFICIENT TIME FRAME FOR DESIGN AND TENDER PROCESS	FINANCIAL / END USER SAFETY	ENSURE THAT THERE IS SUFFICIENT TIME TO UNDERTAKE THE REQUISITE TASKS, THUS ENSURING THAT OPTIMAL DESIGNS AND CONTRACT DOCUMENTATION IS PRODUCED
	SITE STAFF RESOURCING	FINANCIAL / END USER SAFETY	ENSURE THAT THE BEST PERSONNEL ARE SELECTED. PROPOSED SITE PERSONNEL ARE TO BE APPROVED BY THE RELEVANT PERSONS AT ACSA. EARLY IDENTIFICATION OF CANDIDATES
CONSTRUCTION	SECURITY BREACHES	OPERATIONAL SAFETY	DEDICATED FULL TIME ACSA SECURITY PERSON TO BE APPOINTED WITH THE NECESSARY SUPPORT
	SAFETY OF CONTRACTORS SITE PERSONNEL	SAFETY	INDUCTION TRAINING FOR ALL CONTRACTOR'S PERSONNEL AND AVOP LICENCING. CONTRACTOR TO APPOINT FULL TIME SAFETY OFFICER. AUDITS UNDERTAKEN BY EXTERNAL OHS PRACTITIONER ON A 3 MONTHLY BASIS
	SAFETY OF ENGINEER'S CONSTRUCTION MONITORING STAFF PERSONNEL	SAFETY	INDUCTION TRAINING FOR ALL CONSTRUCTION MONITORING STAFF
	SAFETY OF AIRCRAFT AND PASSENGERS	FINANCIAL / OPERATIONAL SAFETY	CONTRACTOR TO COMPLY WITH THE "MANUAL OF PROCEDURES FOR WORKING AIRSIDE". SITE MONITORING PERSONNEL TO STRICTLY MONITOR AND ENFORCE COMPLIANCE
	FOREIGN OBJECT DAMAGE.(F.O.D.).	FINANCIAL / OPERATIONAL SAFETY	COMPLIANCE WITH THE AIRSIDE PROCEDURE MANUAL AND INSPECTIONS BY THE ENGINEER'S REPRESENTATIVE PRIOR TO THE OPENING OF ANY WORK AREAS
	ENVIRONMENTAL ISSUES	FINANCIAL / TIME	ENVIRONMENTAL CONTROL OFFICER TO BE APPOINTED. MONTHLY AUDITS AND AUDIT REPORTS TO BE UNDERTAKEN
	MAJOR PLANT BREAKDOWNS	FINANCIAL / TIME / OPERATIONAL SAFETY	CONTRACTOR WILL BE CONTRACTUALLY OBLIGED TO HAVE REPLACEMENT PLANT AVAILABLE WITHIN A SPECIFIED PERIOD. IN ADDITTION TO REPLACEMENT PLANT, CONTRACTOR MUST HAVE A CONTINGECY "PLAN" FOR THE IMMEDIATE REMOVAL FROM AIRSIDE OF ANY BROKEN DOWN PLANT ITEMS
	MATERIALS SUPPLY (BITUMEN)	FINANCIAL / TIME	ANY PLANNED DISRUPTIONS (MAINTENANCE) TO BE IDENTIFIED PRIOR TO CONSTRUCTION COMMENCEMENT
	MATERIALS SUPPLY (ASPHALT)	FINANCIAL / TIME / OPERATIONAL SAFETY	DAILY ASPHALT REQUIREMENTS TO BE "LINNKED" TO THE ABILITY OF LOCAL ASPHALT PLANT AND/OR SITE BASED ASPHALT PLANT TO SUPPLY. SUFFICIENT ASPHALT TO BE "ON SITE" PRIOR TO ANY EXCAVATIONS BEING OPENED
	FAILURE TO OPEN FACILITIES FOLLOWING SHIFT	FINANCIAL / OPERATIONAL SAFETY	ACHIEVABLE PRODUCTION RATES TO BE AGREED WITH CONTRACTOR. START UP MEETINGS BEFORE EACH AND EVERY SHIFT WITH AGREEMENT ON THE WORK TO BE UNDERTAKEN DURING THE SHIFT. MEASUREMENT OF WORK AREA TO BE CONFIRMED WITH ENGINEER'S REPRESENTATIVE FOLLOWED BY STRINGENT MONITORING OF THE WORK
	CONSTRUCTION QUALITY	FINANCIAL / END USER SAFETY	IT IS ENVISAGED THAT A SITE LABORATORY WILL BE RECTED. THIS WILL ENABLE TIMEOUS TURN AROUND TIMES FOR TESTING. THE STATISTIACAL JUDGEMENT PLANS AS PER COLTO WILL BE USED FOR ACCEPTANCE CONTROL AND STRINGENT "HANDS ON" SITE MONITORING WILL BE IMPLEMENTED
	CONSTRUCTION CONTRACT PERIOD OVERRUN	FINANCIAL / TIME	EXTENSIONS OF TIME DUE TO INCLEMENT WEATHER CANNOT REALLY BE MITIGATED - WITH THE EXCEPTION OF "ALLOWABLE" DELAYS AS INDICATED IN THE CONTRACT DOCUMENT. EXTENSIONS OF TIME CAUSED BY DESIGN CHANGES OR OTHER REASONS CAN BE MITIGATED BY ENSURING THAT THE DESIGNS AS DOCUMENTED ARE CORRECT AND APPLICABLE AND THAT THE CONTRACT DOCUMENTATION IS AS "WATER TIGHT" AS POSSIBLE

MODERATE SERIOUS POSSIBLY DISASTEROUS

Figure 11 : Design and Construction Stage Risk Register

Design Stage

The design stage of the project can be divided into five (5) individual, but equally integral aspects, viz

- Geometric design of runways and taxiways
- Geometric design of RESA's and side strips
- Pavement structural design for runways and taxiways
- Structural design of RESA's and side strips
- Design of ancillary items

The design rationale for the above design is discussed here after

Runway and Taxiway Geometric Design

The geometric design was undertaken using the "Bentley MX Road" software suite.

The vertical design levels were modelled to follow the existing geometrics as closely as possible (with the addition of the requisite structural overlays). Adjustments to the existing vertical alignment was limited to that necessary for meeting ICAO minimum standards design criteria and achieving the minimum ACSA stipulation of 1.2% for transverse slopes on runway 11/29 and 06/24.

The existing longitudinal profile on both runways was found to be generally compliant in terms of the requisite ICAO criteria. The average longitudinal grade for the "1st and last quarter" of each of the runways was compliant (i.e. 0.7%). There were, however, a number of individual 10 m slopes that were in excess of the maximum 0.8% recommended slope. These minor deviations were addressed during the vertical alignment design.

The existing cross falls on both the runways were all compliant in terms of maximum permissible grade, i.e. all less than the stipulated maximum of 1.5%. This notwithstanding, however, a significant number of areas were discovered where the cross falls were "flatter" than the minimum of 1%.

The rationale for the new runway cross fall design was to create – wherever practicable – a slope of at least 1.2%. The exception to this rule was at the 06/24 and 11/29 intersection and at the intersections of Charlie/Bravo and Alpha taxiways, where a "graphical grading" was undertaken to ensure smooth transitions over these areas whilst still providing adequate stormwater drainage away from the respective runways. A typical illustration of the existing runway cross falls and longitudinal grades is presented in Figure 12

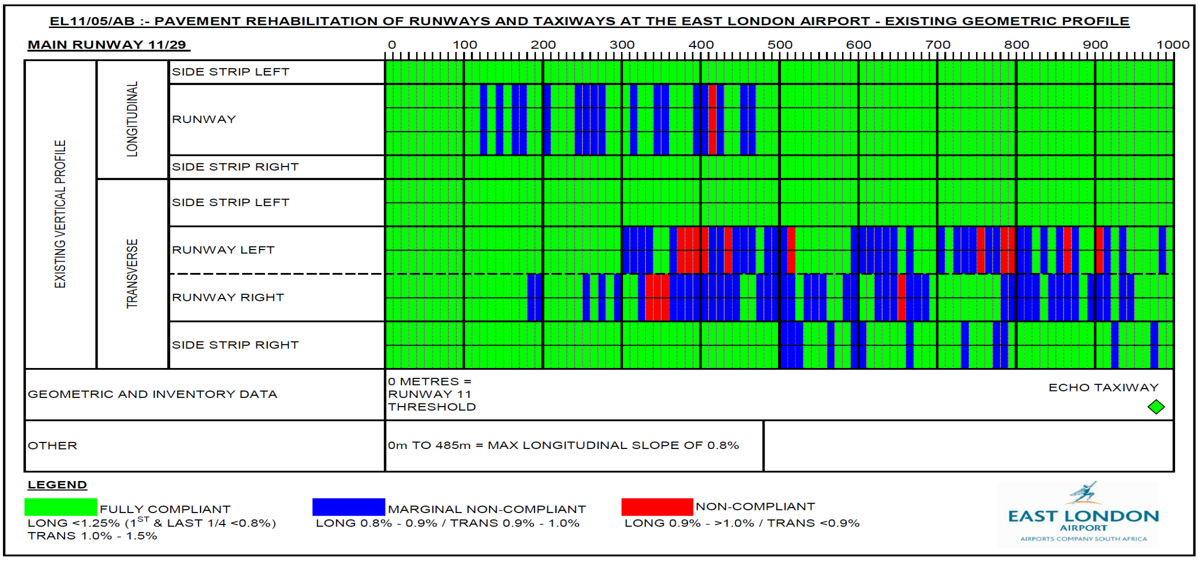

Figure 12 : Existing Longitudinal and Transverse Grades

As can be observed from Figure 12, the cross slopes on the runways, in particular, whilst being generally either fully or marginally ICAO compliant, were very variable and this added to the complexity of the geometric design process. The original design solution for rectification of the variable cross falls (not only varying per 20 metres, but also different right and left slopes at the same chainage) was to utilise variable asphalt thickness for the structural/geometric overlay. In reality, once construction commenced, this approach was modified to using a combination of 3D milling and varying asphalt thickness.

The taxiways were found to be geometrically compliant and, as such, the long and transverse grades were not changed – except at the tie-ins to the new runway levels.

RESA and Side Strip Geometric Design

To satisfy ICAO "recommended" requirements, a RESA should be 300m in length and 150m wide. Longitudinal and transverse slopes must not exceed 5%

In terms of longitudinal and transverse slopes, the four (4) RESA's were found to be generally compliant, the only exception being at RESA 29 where a substantial "hollow" was present at approximately 160m from the runway threshold. It is thought that the RESA was constructed in this way with the intention that the hollow would act as a strormwater drainage channel. A hydrological analysis was undertaken on the catchment areas for this channel, and it was established that no drainage measures were required. As such, the "dip" was eradicated by means of a "cut to fill" intervention

In terms of dimensions, the existing RESA 11 was found to be 160m long and only 50m in width. The new design created the requisite surface area and significant mass earthworks and layerworks were required to achieve this. RESA 06 was found to be the correct width, but was only 155m in length, terminating at the airport security fence. It was subsequently discovered that ACSA owned the property beyond the fence and a new RESA extension was designed in this area to create the 300m length.

At RESA 24, the existing length of 155m could not be increased as ACSA do not own the property beyond the perimeter fence. In terms of width, the RESA was compliant with the exception of the north western corner where it was curtailed due to the perimeter security road. To address this issue, a retaining structure was designed which enabled the corner to be constructed to specification.

The side strips were found to generally comply with the transverse grade limits of 2.5%. Areas that did not comply were identified during the design process and addressed by shaping. In terms of longitudinal slope the "graded area" of the Runway side strips, by necessity, follows that of the Runway itself. The criteria in terms of maximum longitudinal profile of the side strips of a Code C runway is 1.75%. The maximum individual grade on the two runways is 1.18% and, therefore, it was considered that the side strips were compliant with the ICAO specifications. Isolated areas of side strip non-compliance, in terms of longitudinal grade, were identified and corrected

Pavement Structural and Surfacing Design for Runways and Taxiways

<u>Traffic</u>

The point of departure for the structural design was to establish the cumulative loading for a 15 year structural design period.

Detailed traffic data for 2009 was obtained from ACSA, and formed the basis for the future traffic projections, in particular related to the determination of aircraft loading on the runway and taxiway pavements. The information for 2010 not considered for future projections due to the 2010 FIFA

World Cup peak. The aircraft movements (2009) for each runway and aircraft type are indicated in Table 2.

Table 2: Total Aircraft Movements (Landings) – Base Year 2009

Aircraft Type	Runway 11/29	Runway 06/24	Total
Airbus A319	704	58	762
Boeing 737-800 pax	505	31	536
Boeing 737-200 Freighter	206	41	247
Boeing 737 Advanced pax	37	1	38
Boeing 737-types (total of other)	25	1	26
McDonnell Douglas MD82	303	20	323
McDonnell Douglas MD83	208	12	220
McDonnell Douglas MD87	77	2	79
(BAC) One Eleven 400\475	1	0	1
Canadair Regional Jet 100	1018	67	1085
Canadair Regional Jet 200	807	45	852
Canadair Regional Jet 700	45	4	49
Canadair Regional Jet	185	12	197
British Aerospace Jetstream 41	607	54	661
De Hav.Canada DHC8 Dash 8-300	1099	159	1258
De Hav.Canada DHC8 Dash 8-400	110	7	117
Fokker F.28 Fellowship 4000	14	1	15
Douglas DC-9-30 pax	8	0	8
Total Scheduled Movements 2009	**5959**	**515**	**6474**
Runway Splir (Scheduled)	92%	8%	100%
Light Unscheduled Movements	**5437**	**1258**	**6695**
Runway Splir (Unscheduled)	81%	19%	100%
Total Movements 2009	**11396**	**1773**	**13169**

The monthly distribution of the schedule aircraft movements are shown in Table 3 and graphically illustrated in Figure 13

Table 3 : Scheduled Aircraft Movements (Landings) per Runway (2009)

Month	Rway 11	Rway 29	Rway 06	Rway 24	Total
Jan-09	285	241	14	20	560
Feb-09	280	202	12	13	507
Mar-09	245	248	46	35	574
Apr-09	228	235	35	14	512
May-09	215	297	23	23	558
Jun-09	150	335	33	10	528
Jul-09	157	347	18	15	537
Aug-09	195	325	16	13	549
Sep-09	183	311	13	37	544
Oct-09	268	257	19	31	575
Nov-09	278	232	12	24	546
Dec-09	251	194	8	31	484
Total	**2735**	**3224**	**249**	**266**	**6474**
% Split	**42%**	**50%**	**4%**	**4%**	**100**

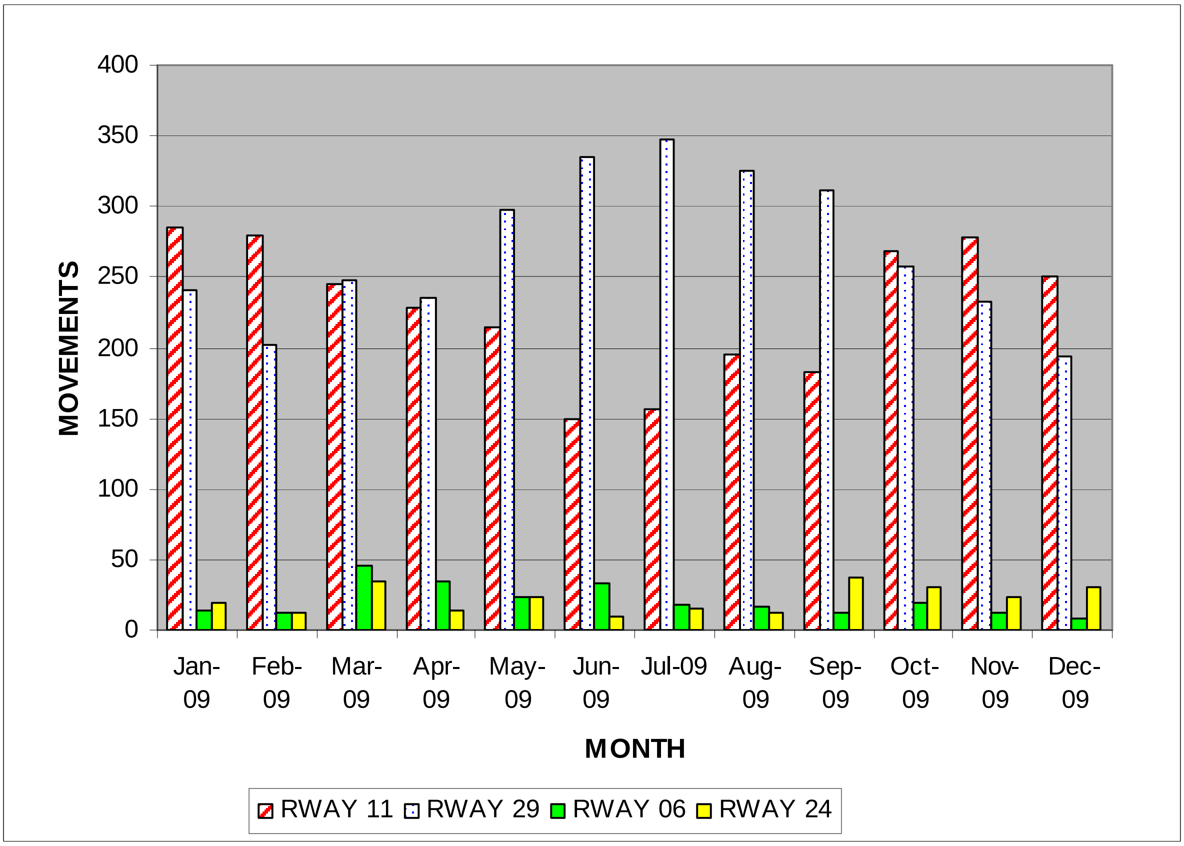

Figure 13 : Monthly Distribution of Aircraft Movements per Runway

As can be seen from Table 3 and Figure 13, Runway 11/29 attracts around 92% of the total scheduled aircraft movements. There is also a distinct difference in aircraft movement when comparing runway 11 and runway 29 during the winter months of May to September. This is due to the prevailing winds during these months i.e. predominantly easterly / south easterly.

Table 4: Landing and Departure Distributions per Runway/Taxiway (2009)

Runway/Taxiway	% of Total Arrivals[2]	Total Arrival (a)	% of Total Departures[2]	Total Departures (b)	Equivalent Total Departures[1] [(a)/4+(b)]
Total arrival/departure		13169		13169	16461
Runway 11/29	92%	12112	92%	12112	15144
Runway 06/24	8%	1053	8%	1053	1317
Alpha taxiway (to runway 11)	35%	4608	50%	6583	7736
Alpha taxiway (to Delta)	55%	7241	48%	6319	8132
Bravo taxiway	20%	2633	5%	658	1317
Charlie taxiway	5%	658	5%	658	823
Delta taxiway	50%	6583	45%	5924	6089
Echo taxiway	5%	658	5%	658	823
Foxtrot taxiway	5%	658	5%	658	823
Golf taxiway	5%	658	5%	658	823

Note: 1) Arriving semi-loaded aircraft typically have a ¼ damage equivalency factor compared to generally fully loaded departing aircraft (low fuel weight); therefore for conversion to loaded departing aircraft divide numbers by 4.

2) Runway and Taxiway splits are been based on schedule and unscheduled flights. The split is based on landing/take off patterns as per Table 3 and in consultation with the local airports management.

The historical growth in aircraft movements and passenger movements is indicated in Table 5 below. To accommodate the increase in passenger demand, Airlines tend to rather use larger (rather than more) aircraft and this explains the lower (compared to passenger increase) growth in aircraft movements.

Table 5: Historical Year to Year Growth Figures in Aircraft and Passenger Movements

	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	Average
Scheduled Aircraft	8.1%	20.4%	-0.2%	-4.4%	2.5%	5.3%
Unscheduled Aircraft	5.1%	8.1%	5.5%	10.9%	5.5%	7.0%
Passengers	20.0%	31.7%	17.9%	6.7%	5.4%	16.3%

FY: ACSA Financial Year ending March
Source: ACSA Master Plan for East London Airport

Based on the discussion with ACSA planning department, national passenger volumes are expected to grow between 5% and 10% over the next 15 years, with the East London Master Plan indicating an expected average passenger growth of approximately 7%.

In order to meet the traffic forecast of 7%, two (2) aircraft scenarios were analysed, namely:

- A 10% growth in the large Code C commercial aircraft and a 0% growth in Code B commercial aircraft
- An 8% growth in the large Code C commercial aircraft and a 4% growth in Code B commercial aircraft

Tables 6(a) and (6b), summarise the above

Table 6(a) : Growth in Aircraft Movements (High Code C growth)

Aircraft Type	2009	Ave Pass	Split	Growth	2026/7	Split
Code C	2242	146	35%	10.0%	9357	69%
Code B	4232	61	65%	0.0%	4232	31%
Total	6474			5.1%	13589	

Table 6(b) : Growth in Aircraft Movements (Lower Code C Growth)

Aircraft Type	2009	Ave Pass	Split	Growth	2026/7	Split
Code C	2242	146	35%	8.0%	7106	69%
Code B	4232	61	65%	4.0%	8798	31%
Total	6474			6.2%	15904	

The aircraft movements for both scenarios was analysed with the FAA approved FAARFIELD software, as well as the modified SA mechanist method, using the Rubicon software. In the latter case, the entire aircraft loading was converted to an equivalent 737 wheel load. The 2009 data was converted to a 2011 base year using a total growth of 5% per year up to and including 2011.

The equivalent wheel loading for the code C aircraft (e.g. Airbus A317, Boeings 737s, MD83/82) range from 0,43 to 1,27, while the loading of the code B commercial aircraft (e.g. Canadair series, Dash 8 series) has a significant lower or immaterial impact on the structural design of the respective pavement structures, with equivalent 737 loads ranging from 0,005 to 0.031).

Light private Cessna type private planes has not been considered for the pavement analysis due to the insignificant impact on the pavements (e.g. one Boeing 737 is equivalent to more than 800 000 Cessna light aircraft)

While the aircraft movement under the “lower” code C growth scenario is approximately 17% higher than the “higher” code C growth (as per tables 4.4 and 4.5), the impact on the structural pavement loading is the opposite with the equivalent 737 loading approximately 16% higher under the “higher” code C growth scenario.

Table 7 presents a summary of the traffic loading analysis of the worst case scenario (10% growth in code C and a 0% growth in code B commercial aircraft), for all the runway and taxiway pavements, in accordance to the aircraft splits as previously discussed

Table 7 : Traffic Loading for Base Year (2011) and Total Design Traffic Loading

Facility	Total Equivalent B737’s for 2011 (Code C)	Total Equivalent B737’s for 2011 (Code B)	Total Equivalent B737’s for 2011 (Code B&C)	Daily Equivalent B737’s for 2011 (Code B&C)	Total Equivalent B737’s for Design Period (2011 to 2026/7)
Runway 11/29	1,850	56	1,907	5.22	64,492.5
Runway 06/24	129	6	135	0.37	4,526.7
Alpha taxiway (to runway 11)	930	29	960	2.63	32,439.0
Alpha taxiway (to Delta)	978	31	1,009	2.76	34,095.5
Bravo taxiway	158	5	163	0.45	5,521.5
Charlie taxiway	99	3	102	0.28	3,451.0
Delta taxiway	910	29	939	2.57	31,748.8
Echo taxiway	99	3	102	0.28	3,451.0

Note: Foxtrot and Golf taxiways are not included as Foxtrot is closed and Golf only caters for light, unscheduled aircraft

The above traffic loading statistics were used in the structural analysis of the respective runway and taxiway pavements and the subsequent rehabilitation designs to provide 15 years of structural design capacity.

Deflection Analysis

As previously discussed, Falling Weight Deflectometer (FWD) deflection measurements were taken in May 2011.

The measurements were taken on the runways at 20m intervals at 3m left and right of centre line and at 80m intervals for 8m and 20m each side of the centre line.

Taxiways were tested at 20m intervals for 3m left and right of centre line and 20m intervals on centreline.

The deflection bowl data was measured at offsets of 0, 200, 300, 450, 600, 900, 1 200, 1 500 and 1 800 mm (horizontally) from the falling weight. The FWD load was applied at 120 kN with contact pressures of 1 698 kPa.

A summary of the 90th percentile deflection values, as isolated for each relevant section, are given in Table 8.

Table 8 : Deflection Bowl Parameters for Different Sections

Runway/ Taxiway	Section	Length (m)	Deflection Parameters at 120 kN FWD Loading			
			Values at 90th Percentile Design Area#			
			Max Deflection	BLI *	MLI **	LLI ***
Runway 11/29	3 Metres Right of C/L	1940	1220	464	377	187
Runway 06/24	3 Metres Right of C/L	1590	1145	541	330	124
Alpha Taxiway	3 Metres Left of C/L	890	674	319	166	74
Bravo Taxiway	3 Metres Right of C/L	140	787	279	242	114
Charlie Taxiway	3 Metres Left of C/L	180	875	379	219	113
Delta Taxiway	3 Metres Left of C/L	1338	722	342	192	80
Echo Taxiway	3 Metres Left of C/L	90	848	404	258	132

Note:

BLI* = Deflection at 0 mm – deflections at 300 mm; indicative of base stiffness
MLI** = Deflection at 300 mm – deflections at 600 mm; indicative of subbase stiffness
LLI*** = Deflection at 600 mm - deflections at 900 mm; indicative of subgrade stiffness.
= The 90th Percentile Design Area relates to the identified "failed" section (in terms of maximum deflection) which will be used as the representative "weakest" area identified statistically from test data.

The 90th percentile (statistical weakest) deflection data characteristics, together with the pavement layer profiles identified during the assessment stage materials investigation were used as a basis for back-calculation and analysis of the unique mechanical properties of each uniform pavement section as identified above.

The ELSYM5 elastic layer computer programme and the Rubicon package was used to simulate pavement deflections under the 120 kN FWD "wheel loads". The back-calculated mechanical properties obtained during the deflection simulation exercise are given in Tables 9(a) to 9(g).

Table 9(a) : Representative Mechanical Properties: Runway 11/29

Layer Thickness (mm)	Material Type	E- Value (mPa)
		Centre 20 m
115	Asphalt (AC)	3 000
110	Macadam G3	370
310	G5	130
340	G6	130
Semi infinite	G7	300

***Note:** Poisson ratio of the asphalt layer taken as 0.44; 0.35 ratio used for other layers

The resilient modulus value of the 115 mm asphalt material, back-calculated for Runway 11/29 is 3000 mPa. This is typical for aged asphalt layers which are relatively stiff.

The back-calculated stiffness of the G3 base layers which was found to be ±370 mPa at the 90th percentile weakest deflection point on the centre areas.

Back-calculations of layer moduli for the G5/6 subbase and selected layer of 130 MPa each are typical values from these layers after an extensive service life. The entire airport is constructed on "bed rock" and the subgrade was simulated to be a rigid foundation at a depth of approximately 2.0 m below the surface.

Table 9(b): Representative Mechanical Properties: Runway 06/24

Layer Thickness (mm)	Material Type	E- Value (mPa)
		Centre 20m
110	Asphalt (AC)	3000
100	Macadam G3	520
220	G5	250
445	G6	200
Semi infinite	In-situ gravel	120

As for runway 11/29, the stiffness of the 110 mm asphalt material was back-calculated at 3000 mPa.

The back-calculated stiffness of the G3 base layers was found to be ±520 mPa at the 90th percentile weakest deflection point on the centre areas which is a relative good value taking into account the age of the layer. This is probably due to the smaller historical loading compared to the main runway.

Back-calculated layer stiffness values for the G5/6 subbase and selected layer of 250 mPa to 200 mPa respectively are also relative good values taking into account the age of the pavement.

The back calculated stiffness values of the taxiways investigated is reported in tables 9(c) to 9(g). Most of the pavements have a similar residual life and material quality, therefore explaining the similar values reported.

Table 9(c) : Representative Mechanical Properties: Alpha Taxiway

Layer Thickness (mm)	Material Type	E- Value (mPa)
		Centre 15m
100	Asphalt (AC)	3000
150	G3	600
150	G4	500
400	G6	450
Semi infinite	In-situ gravel/G7	300

Table 9(d) : Representative Mechanical Properties: Bravo Taxiway

Layer Thickness (mm)	Material Type	E- Value (mPa)
		Centre 15m
130	Asphalt (AC)	3000
150	G3	550
150	G4	350
400	G6	170
Semi infinite	In-situ gravel/G7	400

Table 9 (e) : Representative Mechanical Properties: Charlie Taxiway

Layer Thickness (mm)	Material Type	E- Value (mPa)
		Centre 15m
110	Asphalt (AC)	3000
170	G3	580
320	G4	320
350	G6	160
Semi infinite	In-situ gravel/G7	350

Table 9 (f) : Representative Mechanical Properties: Delta Taxiway

Layer Thickness (mm)	Material Type	E- Value (mPa)
		Centre 15m
110	Asphalt (AC)	3000
150	G3	580
160	G4	520
440	G6	360
Semi infinite	In-situ gravel/G7	400

Table 9 (g) : Representative Mechanical Properties: Echo Taxiway

Layer Thickness (mm)	Material Type	E- Value (mPa)
		Centre 15m
110	Asphalt (AC)	3000
150	G3	500
160	G4	250
380	G6	200
Semi infinite	In-situ gravel/G7	450

The stiffness values of the asphalt material, back-calculated for all the taxiways, was found to be 3000 mPa – as for the runways.

The back-calculated stiffness of the G3 base layers which was found to similar for all taxiway pavements and calculated to be in the range of 500mPa to 600mPa at the 90th percentile weakest deflection point on the centre areas which is a good value and probably due to the fact that the material was found to be "lightly stabilised". Back-calculated layer stiffness values for the G4/6 subbase and selected layer also have relatively good stiffness characteristics.

The above layer moduli were used for input into the Faarfield analysis software, with the resultant pavement designs being compared / verified with the more fundamentally based SA mechanistic design method. In general, the results derived from both methods were comparable. When considering the final recommended pavement structures for the respective runways, the following factors were also considered:

- Critical loadings is normally only in the first 25% of the takeoff zone with the remainder of the runway subjected to significantly lower wheel loads.
- The wandering of the planes on the runway is also relatively high and this distributes the load more across the runway.
- Requisite geometric corrections (eg improvement to existing crossfalls)

Table 10, below, presents the remaining life of the various runways and taxiways as derived from the mechanistic analysis process and also as estimated from the visual condition.

Table 10 : Estimated Remaining Life

Facility	Section	Annual Load (Equivalent Aircraft)	Remaining Life (Equivalent Aircraft)*		From Visual Assessment
		B737-800's	B737's	Years	Years
Runway 11/29	Centre	1,850	2 500	1-2#	0-1
Runway 06/24	Centre	129	250	1-2#	0**
Alpha Taxiway – to 11/29	Centre	930	1 500	1-2#	0-2
Alpha Taxiway – to Delta	Centre	978	1 500	1-2#	0-2
Bravo Taxiway	Centre	158	300	2-3	2-4
Charlie Taxiway	Centre	99	200	2-4	0-2
Delta Taxiway	Centre	910	1 500	1-2#	0-2
Echo Taxiway	Centre	99	200	2-4	0-2

Note: * Remaining life calculations based on SA Mechanistic Design Technique and "Initial minus Accumulated traffic" calculations

Structurally 1 to 2 years; however surface conditions (FOD risk etc) wise this area is at the end of its life and surface layers delamination can follows if rehabilitated in time.

** Existing life non-existent due to surfacing condition

Based on the analysis of the findings of the assessment and subsequent analysis of the various test data, the following remedial actions were identified as given in Table(s) 11(a) and 11(b)

Table 11(a) : Remedial Actions Runways 06/24 and 11/29

Runway	**Centre Pavement Structure 20m Wide**	**Outer Pavement Structure 2 x 12.5m Wide**
Main Runway 11/29	• 80-60mm Structural and Geometric Correction Asphalt Overlay Tapering to 45mm at Transverse Edges • 45mm Combined Friction and Upper Structural Overlay	• Mill and 50mm Inlay • 45mm Asphalt Overlay Tapering to 30mm at Transverse Edges. • 45mm Combined Friction and Upper Structural Overlay
Secondary Runway 06/24	• 65-45mm Asphalt Inlay tapered to 45mm on outer edges • 45mm Combined Friction and Upper Structural Overlay	• Selected Areas 50mm Mill and Asphalt inlay. • 45mm Combined Friction and Upper Structural Overlay Tapered to 40mm

Table 11(b) : Remedial Actions to Taxiways

Taxiway	**Centre Pavement Structure 15m Wide**	**Outer Pavement Structure 2 x 7.5m Wide**
Alpha	• 60mm Mill and Asphalt Inlay • 50mm Asphalt Overlay	• 40mm Mill and Asphalt Inlay • 50mm Asphalt Overlay
Bravo	• Selective Mill (50mm) and Asphalt Inlay (20% of area) • 50mm Asphalt Overlay	• Selective mill (40mm) and Asphalt Inlay (20% of area) • 50mm Asphalt Overlay
Charlie	• Selective Mill (50mm) and Asphalt inlay (20% of Central Area) • 50mm Asphalt Overlay	• Selective Mill (40mm) and Asphalt Inlay (20% of area) • 50mm Asphalt Overlay
Delta	• 50mm Mill and Asphalt Inlay • 50mm Asphalt Overlay	• 40mm Mill and Asphalt Inlay • 50mm Asphalt Overlay
Echo	• Selective Mill (50mm) and Asphalt Inlay (20% of area) • 50mm Asphalt Overlay	• Selective mill (40mm) and Asphalt inlay (20% of Area) • 50mm Asphalt Overlay
Foxtrot and Golf	• Surface Rejuvination	• Surface Rejuvination

The above remedial actions are further illustrated in Figure(s) 14 to 18

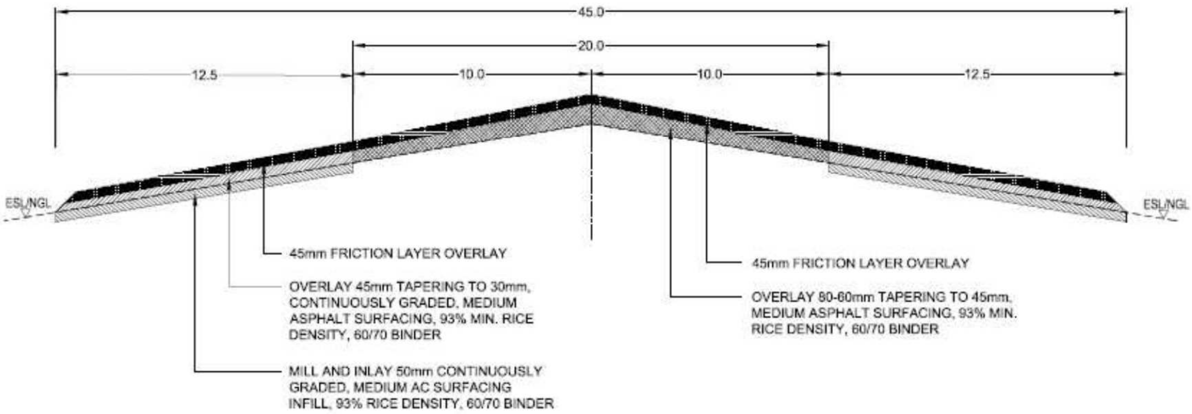

Figure 14 : Runway 11/29

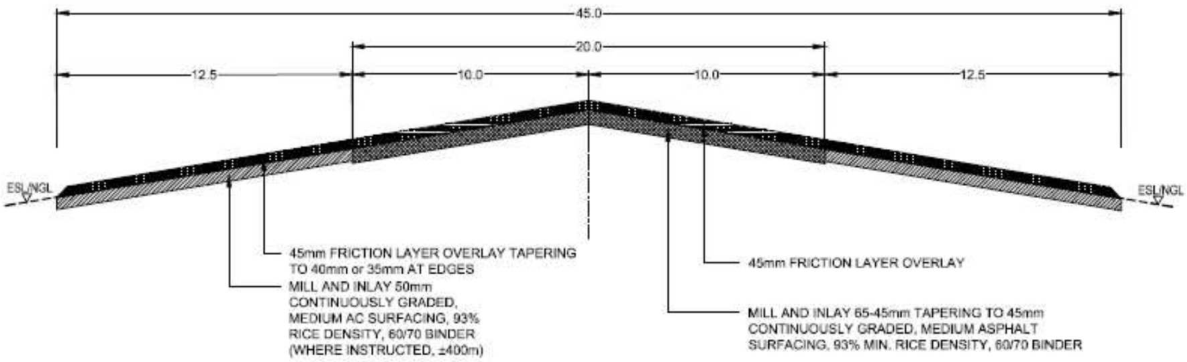

Figure 15 : Runway 06/24

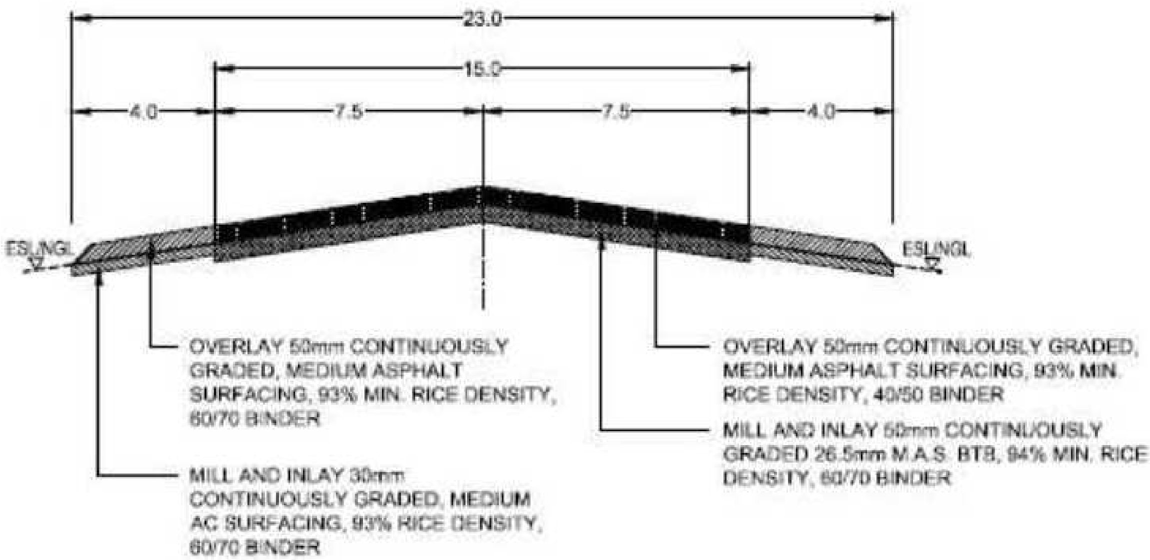

Figure 16 : Alpha Taxiway

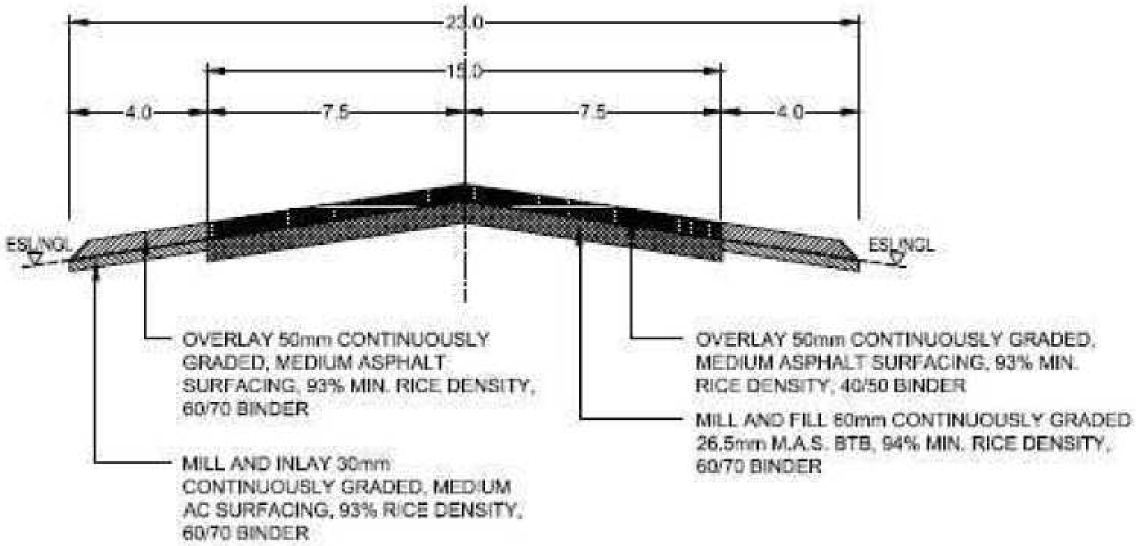

Figure 17 : Delta Taxiway

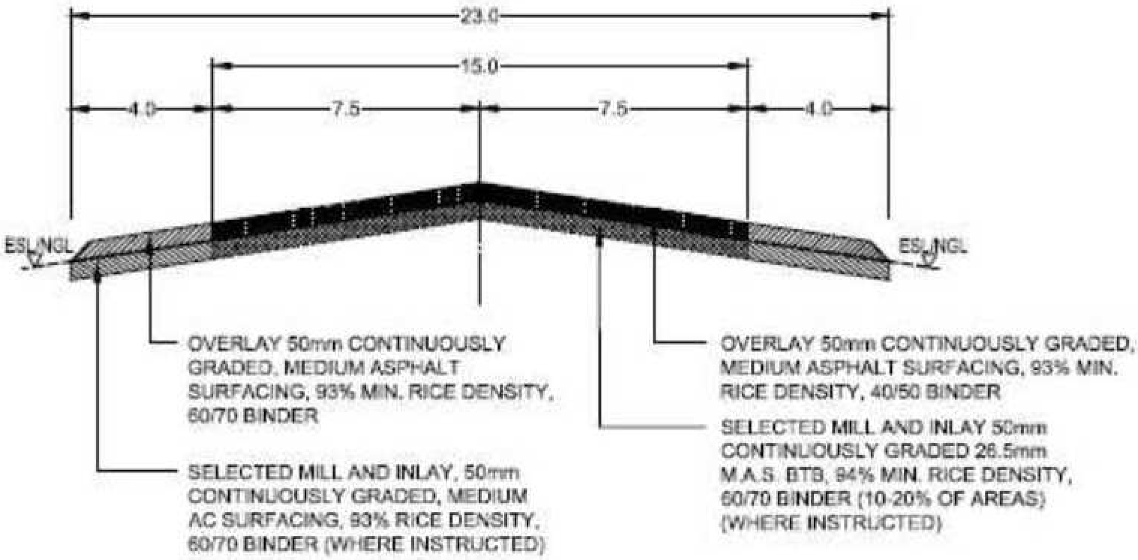

Figure 18 : Bravo; Charlie and Echo Taxiway

<u>Surfacing Design</u>

Traditionally, conventional continuous graded asphalt surfacing mixes were used on South African airport runways. Friction measurements and recent maintenance history show costly grooving and rubber removals are frequently required to restore runway friction levels when non-compliant and/or borderline friction values are reached. Grooving of the surfacing layer and destructive “high water pressure” rubber removals also cause these conventional surfacing layers to age and disintegrate prematurely, eventually resulting in structural surfacing and even deeper base layer damage and eventual dangerous potholing or interlayer shear failures if not replaced in time.

In addition to the costly annual maintenance effort, the fact that only 7 to 8 years life are obtainable from these traditional surfacing layers, render it an extremely costly surfacing option. Also for new runways (and even resurfaced runways), the level of friction provided (0.4 – 0.55) by this conventional surfacing layers, is marginal to unacceptably low when compare to the ICAO required minimum levels of 0.74 target or 0.53 maintenance level (as measured by the Griptester device at 65 km/h, 1 mm water film.

The following essential runway safety, functionality and design principles, as identified from the ICAO requirements and other applicable international sources, were included in the identification of the optimum new surfacing layer/system for the runways 06/24 and 11/29:

- The specialist friction course layer to increase friction values to consistent, ICAO acceptable, standards (in excess of 0.65 to 0.74, Griptester measured at 65 km/h). In addition these layers typically should have +13 to 15 year's life span to render it optimally cost-effective and with a low impact on runway operations.
- Riding quality optimisation – the designed layer must accommodate the utilisation of best practise paving and construction methodologies as to obtain maximum final riding quality and water run-off.
- Friction properties – skid resistance and sealing efficiency, durability and aqua-plane skidding prevention to be obtained through special mix and grading type (i.e. Semi-Open Graded, etc), aggregate selection and bituminous binder durability enhancement.
- Optimal availability of runway – utilising long-life resurfacing products, uncomplicated construction methodologies to accelerate construction, and minimised occupation time periods should be worked into the optimum system.

It is also noted that the suitability and cost-effectiveness of a friction layer should never be analysed in isolation from its immediate underlying substrata (normally a bituminous bound base or previous surfacing layer). Table 12, presents a selection of surfacing layers used at South African overseas airports

Table 12 : Surfacing Layer Alternatives

Assessment Criteria	GAP Graded Type Mixes SMA/Semi-Open/ Friction	Continuous Graded (Ungrooved)	Grooved Mixes Continuous	Antiskid
Expected ICAO Compliance#	Complies. Water Cutting to Remove Binder Film and Mastic Can be Used to Optimise Friction On New Runways for The Less Open Variants (i.e. SMA)	Does Not Comply With Friction in SADEC Region on New Runways. Resurfacing Complies due to Lower ICAO Criteria	Does Not Comply With Friction in SADEC Region on New Runways. Resurfacing Complies due to Lower ICAO Criteria	Comply Fully with ICAO in European Applications
Expected life	15 – 20 years	10 – 12 years	8 – 10 years	7 - 9 Years in Touch Down Areas
Usage in SADEC Region	• King Shaka International • Sections at Cape Town International • ORTIA 03R/21L and Bloemfontein/ Upington/	• Cape Town Int. (01/19) • ORTIA 03L/21R take-off runway • Kruger Mpumalanga International • East London	Portions of PEIA On Touch Down Zones	None
International Examples	Various in France, Belgium, USA	Various European and USA	Various UK	Athens, Amsterdam
Structural Contribution	Partial	Yes	Partial	No

Following a series of trials at the East London Airport, it was concluded that a modified Bitumen Rubber Semi Open Graded (BRASO) surfacing layer would provide the best performance on the runways at the airport as this mix typically enhances both durability and friction values. Some of the more important characteristics of the BRASO mix are highlighted below:

(a) Durability

Life expectancies of these systems were identified as approximately 13 to 15 years. Problems closing-up of the mix (if too high binder contents or unstable gradings) can be experienced and must be taken care of during design. Experienced design can effectively prevent these risks and comprehensive best-practise design and construction methodologies exist in RSA.

(b) Cost Effectiveness and Availability

Detailed cost analysis shows this to be approximately R120/m^2 at a thickness of 45 mm. Full product cost (including P&G's, design, etc will vary between R170/m^2 to R190/m^2 for new runways to "resurfacing-of-existing-runways" respectively. The layer also serves as part of the structural load-carrying pavement structure. The only extra-over cost (compared to conventional AC layers) is, therefore, the binder modification at a cost of ±R25/m^2. This product was also readily available from the local asphalt plant (only one in East London).

(c) Safety

The product is similar to conventional continuous graded asphalt surfacing in terms of layer stability and safety. Long track records of FOD free application on runways exist for similar BRASO mixes in Europe. Due to its bitumen rubber binder modification, end-of-life conditions will most probably be more durable and with less break-up risk than for conventional asphalt surfacing mixes.

(d) Salvage Value

A positive salvage value of approximately 30% of the layer cost (say R36/m^2) is estimated due to its high durability and fatigue resistance (can be used as new upper asphalt layer for direct resurfacing or consider as part of "structural base" layers).

Figures 19(a) to 19(e) illustrate the various trial sections

Figure : 19(a) Existing Asphalt (AC) Surfacing With Very Little Surface Voids

Figure 19(b) : UTFC Friction Layer Trial (Many Surface and Interconnected Voids)

Figure 19(c) : Modified Semi-Open Graded Asphalt Friction Layer Trial (Many Surface Voids and Course Surface Texture)

Figure 19(d) : Water Run-Off Comparison with Existing AC Surfacing

Structural Design of RESA's and Side Strips

With the exception of RESA 11, and, possibly the side strips of runway 11/29, the laboratory and DCP derived CBR values can be described as generally being lower than the ICAO recommended values.

It was concluded that it could be possible to increase the CBR values of the side strips of runway 11/29 and, maybe even the 29 RESA, by the provision of increased compaction (+97% Mod AASHTO density) of the in-situ materials. This notwithstanding, the lack of an adequately dense "anvil" in the material immediately below the -150mm to -350mm horizon, was seen as a possible problem in achieving the necessary higher compaction effort.

Given the marginal, material quality in the side strips and RESA (with the exception of 11 RESA), alternative methods were considered to increase the bearing capacity of these areas to an ICAO compliant minimum standard, these included:

- Grass Blocks
- Cellular Confinement Systems
- Mechanical Modification
- Chemical Stabilisation

The point of departure in the selection of the method was firstly safety, secondly cost and thirdly ease of construction. Following detailed laboratory and field testing, it was evident that, if the in-situ material was mechanically modified with a good quality granular material (50% G5), compliant CBR values could be achieved without excessive compaction. As such, this was the selected methodology for increasing bearing capacities in the RESA's and Strips.

Ancillary Works

The main ancillary works were concerned with sub-surface and surface drainage. Whilst a significant amount of new electrical installations were undertaken, these were designed by a sub-consultant.

In terms of surface drainage, the main aspect was the extension of the existing culvert beneath the runway 11 RESA and the associated erosion protection of the over flow channel. Hydrology/Hydraulic calculations showed the existing 1200mm pipe to be adequately sized and, therefore, it only needed extending as opposed to being replaced.

In addition to the above, there were several areas (namely adjacent to the ILS building at both runway 11 and runway 29 touchdown areas) where ponding water occurred after rain. These areas were identified from the topographical survey and were drained into the existing stormwater drainage system.

Regarding sub-surface drainage, the runways and taxiways at the East London airport are surrounded by a sub-surface drainage system approximately 0.5m away from and 1.0 metres below the edge of the runway and taxiway surfacing.

Based on high pressure water testing of these conduits, it was apparent that they were blocked and allowance for cleansing these drains was made in the Bill of Quantities. To allow for sections that needed replacement, this was also allowed for in the BoQ.

CONSTRUCTION STAGE

Tender Process

Following the conclusion of the design stage in August 2011, tender documentation was prepared for the construction contract. The contract was advertised in the South African national press in late September 2011. Tenders closed on 12 October 2011 with the tender evaluation process being completed on 24 November of the same year. The contract was awarded to Power Construction (Pty) Ltd on 01 December in the amount of R190 Million (AU$ 20 Million) which was within 3% of the consulting engineer's estimate.

During this period a notification was given to the Aeronautical Information Publication (AIP) that construction works would be commencing in January 2012 for a period of 16 months. The Aeronautical Information Regulation and Control (AIRAC) became effective on 15 December 2011.

Programme

The quality of the construction was, obviously, an important facet for all the works undertaken but, the runways were of critical importance in terms of riding quality, geometrics, friction etc. As such, it was a stipulation in the tender documents that the runway and taxiway construction would be undertaken as follows:

1 Taxiways
2 Runway 06/24
3 Runway 11/29

The main constraint on the contractor was the limited working times which were generally confined to the period between the last aircraft departure and 05:00 the following morning (around 5 hours for actual work with 2 hours allowed for clean-up operations). The evacuation time on Saturday's and Sundays was extended until 07:00 and work on the taxiways could be undertaken, within certain areas, whilst the airport was still operational

By adopting the above approach, it was considered that the contractor's staff would be fully aware of the challenges of working at a "live" airport by the time construction commenced on the secondary and then main runways.

Works on the RESA's, side strips, drainage, electrical installations etc, were programmed to run concurrently with the runway and taxiway works. The initial contract completion date was 25 April 2013 however, due to rain delays exceeding that allowable, the final completion date would eventually be 24 June 2013

Site Management / Risk Mitigation / Quality Control

Unlike a road rehabilitation contract, the site of construction works at an airport is comparatively confined. This notwithstanding, there were numerous activities that were running concurrently and all needed to be monitored. The consulting engineers site team consisted of the following:

- Full time Resident Engineer
- Full Time Assistant Resident Engineer
- Full Time Materials Technician x 3

In addition to the above, the consultants Project Leader visited site at least twice a week (in addition to attending site and technical meetings which were held every second week)

The most important aspect of the site management was the mitigation of potential risk to aircraft, passengers, site staff and disruption of airport operations due to the construction works. As such, a nightly "kick off" meeting was held before every shift, present at which were all the contractors supervisory staff, traffic safety officer, escort personnel and the Resident Engineer's team. The purpose of these meetings was to discuss exactly what work was planned for the night and, due to the fact that the airside had to be vacated in an operational condition by 05:00 each morning, to set completion times for various work items. Routes to be used by construction traffic were also decided upon.

The construction traffic was required to operate within strict regulations as determined on a daily basis by the Resident Engineer (RE), the Air Traffic Navigation Control centre (ATNC) and the contractor's Traffic Safety Officer (TSO). The key Contractor's personnel (or external escorts utilised) were required to obtain airport radio licences and all plant and persons functioning within the airport grounds were compelled to be in constant radio contact with the ATNC centre, the Fire Brigade, the SSO and the RE personnel.

The TSO was ultimately responsible for co-ordinating and monitoring of all construction activities on site and no area was opened or re-opened to airport traffic unless inspected and declared safe by the TSO and accepted by a representative of ACSA.

In addition to the above, ALL persons employed on the project were required to undergo and pass the airside induction course. In addition, drivers and plant operators were required to obtain an airside vehicle operating permit (AVOP)/

Due to the careful planning and management of the construction process not one shift (out of 374) vacated the airside after the cut off time – though there were some close shaves!

A further risk mitigation measure that was stipulated in the tender documentation was the requirement that stand by Plant be on site at all times. As much of the work involved milling into the existing runways and taxiways, it is obvious that these excavations needed to be re-instated prior to the first landing. The plant items included a stand by paver and milling machine which could, if the "main" plant broke down, step in to finish the works by the requisite time

In terms of quality control, a full scale asphalt laboratory was established at the asphalt plant by the consulting engineer and manned by experienced materials technicians. This lab worked independently of the plant laboratory and undertook Marshall testing on each batch of asphalt produced. Binder content and grading results were available to the site team even before the delivery trucks arrived on site. For record purposes, each truck load of asphalt was referenced to exactly where the asphalt was paved.

Other control tests included the drilling of cores, checking of levels and macro texture testing.

Rehabilitation of Taxiways

As discussed previously, no geometric alterations to the taxiways was required (except at the tie-ins at runways) as, such, the rehabilitation of the taxiway pavements was relatively straight forward. On the main taxiways, ie Delta and Alpha, the existing asphalt was milled to a depth of between 60 and 80mm in the centre portion and reinstated with 26.5mm hot asphalt base (40/50 penetration binder, target BC 4.5%, VIM 4.5%, minimum compaction 94% MTD).

The shoulders were milled to between 30-40mm and inlaid with 13.2mm wearing course asphalt (60/70 pen)

On the remaining taxiways (except Foxtrot and Golf, which were in relatively better condition), selective milling of distressed areas was undertaken and repaired either with the 26.5mm or 13mm mix dependant on location and depth

Following the repairs to the existing pavement, a 50mm 13.2mm continuously graded asphalt (target BC 5.2, VIM 4.8 and compacted to minimum 93% MTD) was paved as the new wearing course on all the taxiways except Foxtrot and Golf, where a surface rejuvenator was applied due to their relatively good condition and low usage levels.

To prevent over compaction, a maximum density in place density of 96% MTD was specified for all asphalt layers.

The main constraint during the overlay process was that, at the end of each shift, the asphalt had to be ramped at no more than 2.5% and “keyed in” to be flush with the surface. This ramp was then milled back at the start of the subsequent shift to create a vertical joint for the next paving section.

The taxiway works were undertaken without incident and completed within programme

Rehabilitation of Secondary (06/24) Runway

Following the completion of the taxiways work progressed to runway 06/24. As previously discussed, the shoulders of this runway were rehabilitated during 2010 with a mill and fill operation and, as such, no remedial work was required on these areas except for relatively small areas at the intersection with runway 11/29 .

The centre portion, however, was in an advanced stage of distress with dry, oxidized binder and cracking of the asphalt. The entire centre portion of this runway was milled to a depth of between 45-65mm and inlaid with 13.2mm continuously graded asphalt. To ensure that tight, compacted joints tandem paving was utilised thereby negating the issues usually associated with “cold joint” construction

Unlike the taxiways, this runway required geometric improvements due to the existing inadequate camber cross falls between the 06 threshold and 11/29 crossing (from 11/29 crossing to the 24 threshold, the taxiway was at a straight crossfall and, as such, the existing geometry was not changed. The ACSA minimum requirement for the camber cross slopes for this project was 1.2% and this was achieved by fine 3D milling for the centre inlay and also the outer 5 metres of each side of the runway with a variable thickness inlay ie thicker in the middle.

The above process created the requisite cross slopes and the BRASO was then paved, using tandem paving at a constant 45mm thickness.

As for the taxiways, temporary ramps were constructed every night so that the runway could be operational the following day.

Rehabilitation of Main (11/29) Runway

Work on runway 11/29 commenced on the night of 20 August 2012.

In contrast to the secondary runway, it was the shoulders that required pre-treatment in this case and the existing ravelling asphalt was milled to 50mm before inserting a 13.2mm continuously graded asphalt inlay. In order to realise the requisite structural strength for a 15 year structural design period, an 80-95mm overlay was placed (using tandem paving) on the centre portion again using 13.2mm continuously graded asphalt, with 45mm being placed on the shoulders.

To create the specified cross slopes, the centre overlay thickness was tapered to 55mm at the outside with the shoulder overlay tapering from 45mm to 30mm. Whilst this methodology improved the cross slopes dramatically, there were a number of areas where the grades were either too steep (>1.5%) or still to flat (<1.2%) in addition, there were some riding quality issues, particularly between the secondary runway cross over and the 11 threshold.

Regarding the latter, the contractor and site staff were recalled just before Christmas 2012 to mill and pave 400 tonnes of asphalt following complaints by a number of pilots. Whilst being called back to site at this time of the year was not pleasant, both the contractor and consultant staff arrived within 24 hours and the remedial work was completed over two shifts

As for the secondary runway, fine 3D milling (as illustrated in Figure 20) was used to obtain the correct cross slopes and to smooth out the areas of poor riding quality. Once more, 45mm of BRASO was paved as the final surfacing as illustrated in Figure 21.

Figure 20 : 3D Milling

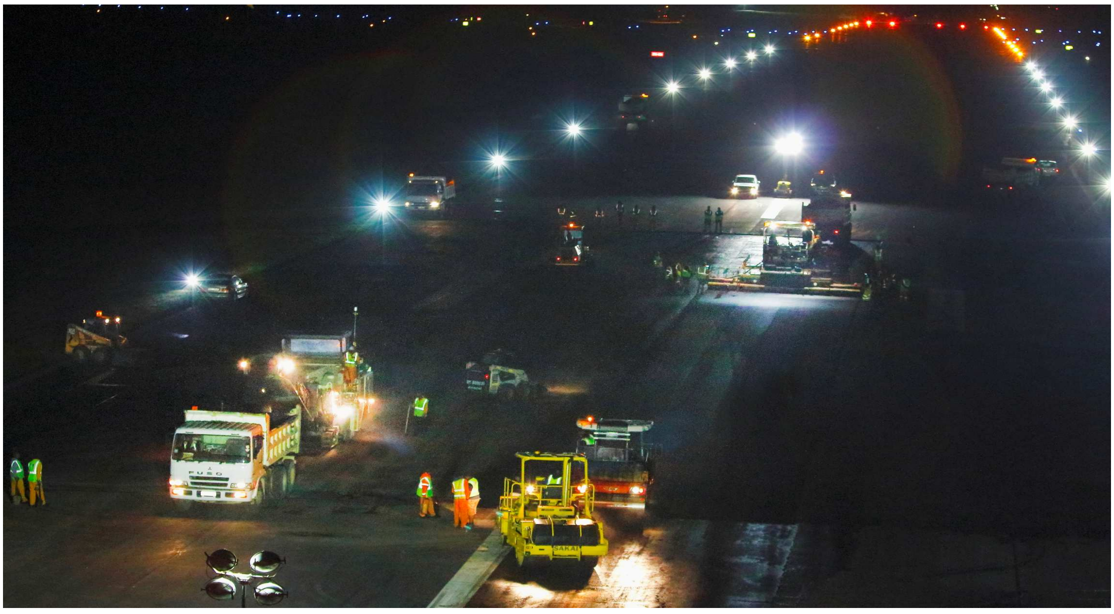

Figure 21 : Paving of BRASO

In addition to the asphalt work, ducts were inserted in the structural / geometric overlay to cater for the future installation of runway centre lighting.

Average asphalt paving production was around 450 tonnes per night which was in line with the contractor’s programme however, due mainly to a lengthy spell of rain during October 2012 (where the equivalent of 50% of the annual rainfall for East London fell in just 21 days), runway 11/29 and with it, the asphalt works, was only completed on 08 June 2013

The “pre” and “post” friction values for both runways, as measured with the griptester are illustrated in Figure(s) 22 and 23 below.

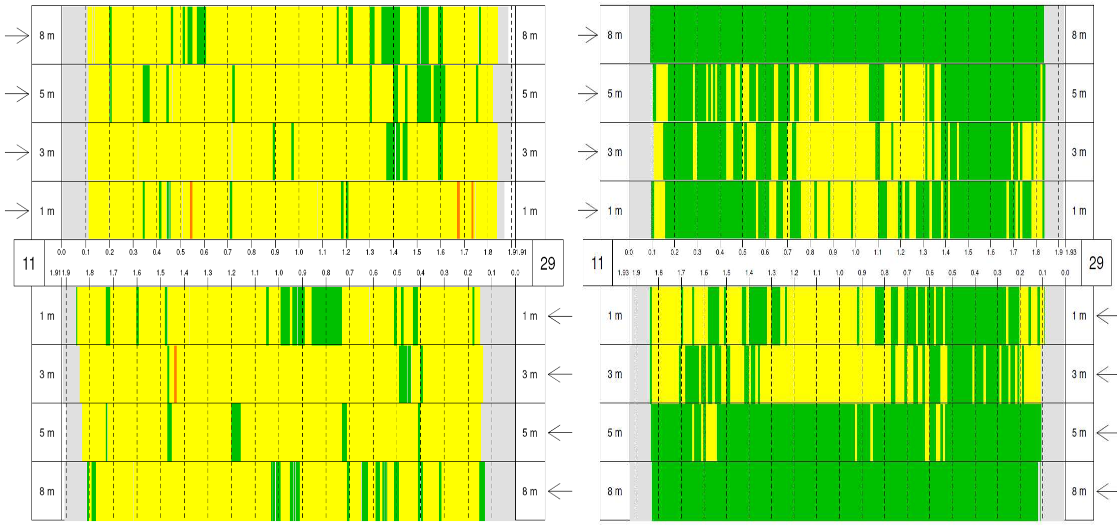

Figure 22 : Friction Map for Runway 11/29 Before (Left) and After (Right) Construction

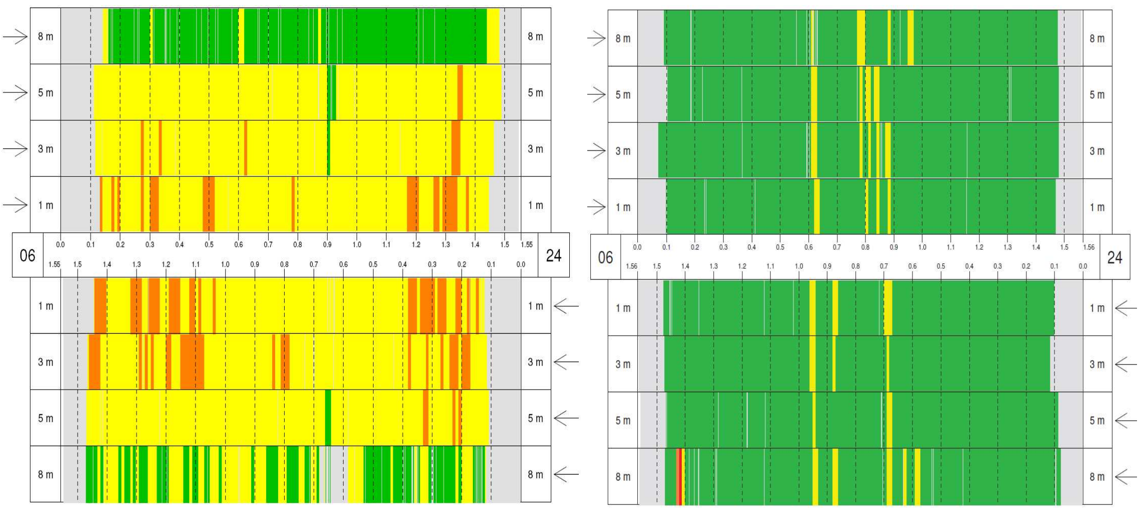

Figure 23 : Friction Map for Runway 06/24 Before (Left) and After (Right) Construction

As can be observed from the above, there has been a dramatic improvement in the friction values (particularly on runway 06/24) as denoted by the “green” areas which denotes a friction value in excess of the design level

<u>Construction of RESA’s</u>

Work on the RESA’s commenced during April 2012, with the installation of fixed “runway closed lights”. The earthworks were started on RESA 24 and 06.

RESA 24 could not be lengthened as discussed previously, and the work mainly included the stripping of the top 150mm, mechanical modification of 150mm-350mm depth by the addition of 50% G5 gravel, shaping, top soiling and hydro-seeding.

One geometric aspect that was addressed was the extension of the north western corner to create a “square” shape. Due to the fact that the level of the RESA was around 8 metres higher than the perimeter road, a retaining structure was required as illustrated in Figure 24 below.

Figure 24 : Retaining Wall at RESA 24

In addition to the strengthening and grading of RESA 06, a new “extension” was also constructed to provide the ICAO recommended length of 300m.

The extension also involved a new portion of perimeter road, security fencing, lighting, security cameras and PIDS (Perimeter Intrusion Detection System).

As the PIDS is still being installed, the existing fence etc remains in place until the new security system is operational as shown in Figure 25 below.

Figure 25 : RESA 06 Extension

The upgrading of RESA 11 entailed not only strengthening and shaping of the existing RESA, but also widening and lengthening and extending a culvert. A further constraint was the necessity to work between lighting and ILS antennae.

Whilst undertaking the mass earthworks, saturated sub-soil conditions were encountered and a dump rock pioneer layer was required to provide stability for the platform construction.

Figure 26 shows the RESA before construction whilst Figure 27 illustrates the post construction RESA . (The pre-extension RESA 06 is also indicated in Figure 26)

Figure 26 : RESA 11 Before Upgrade

Figure 27 : RESA 11 After Upgrade

As for the other areas, RESA 29 required strengthening of the material between 0-150mm and, in addition, also required significant cut to fill earthworks to eradicate a large hollow in the middle of the RESA. Figures 28 and 29, over leaf, illustrate the during and after construction conditions


Figure 28 : RESA 29 During Construction


Figure 29 : RESA 29 After Upgrade

As discussed, the upgrading of RESA's 11 and 29 involved significant earthworks to achieve the desired geometric footprint and grades. Midway through the work, it was reported by the Air Traffic and Navigation Service (ATNS), that the 29 ILS was issuing an "out of limit" signal. It was discovered that changing the levels in front of the ILS antennae by more than 300mm affected the accuracy of the signals.

The ILS at both thresholds was re-calibrated and all work was stopped in these areas. Fortunately, the ILS instrumentation was scheduled for replacement three (3) weeks after the incident and, as this entailed switching off the system (first at threshold 11, then at threshold 11), work could re-commence during the shutdown period. Whilst this was indeed fortunate, the shutdown period was only for 10 days per ILS and, as an anticipated 22 day's work was still outstanding at each RESA, the contractor was requested to accelerate the Works (at an obvious cost) to fit in with the allowable timeframes.

By undertaking day and night shifts and bringing in additional plant and manpower, both RESA's were finished in the stipulated period – in the case of the 11 ILS this was achieved with 2 hours to spare before the calibration flight made took their measurements!

The side strips were re-graded where necessary

Perimeter Road

The perimeter security road at the East London Airport is 16 kilometres in length and was, prior to the undertaking of this project, a 3m wide dirt road which, during wet weather, was virtually impassable – this was obviously not an acceptable situation. This issue was raised by ACSA at an early stage of the design process with a request that an "all weather" road be provided.

Whilst it would have been simple to construct a conventional road, it was considered financially and environmentally prudent to rather use the RAP that was milled from the runways and taxiways. RAP millings were stockpiled at various locations around the airfield and then taken to the perimeter road where the material was spread by motor grader +/- 100mm thick. Bituminous emulsion was sprayed (1.5% residual BC) and process with the RAP by a recycling machine. Following a final trim, the layer was compacted.

The new perimeter road, at first glance, appears to be paved with new asphalt and should provide a sustained period of maintenance free service

Drainage

In terms of stormwater drainage, the main construction involved the extension of a 1200mm concrete culvert pipe at the 11 RESA. The extension was required due to the widening of the RESA. An additional 60m of pipe was installed and laid with open joints (encased in single sized stone and geofabric) to enable the pipe to also act as a sub-soil drain. To prevent scour at the outlet, gabion mattresses were placed.

The existing sub surface drainage system around the runways and taxiways was cleansed by high pressure water jetting and, following this operation, was found to function adequately

Additional Work

Various additional works were added to the contract at various stages and are summarised below:

- Resurfacing of the main access road to the Airport
- Resurfacing of airside service roads
- Removal of alien vegetation
- Installation of a new airside gate for the general aviation area
- Replacement of grid inlets at all existing drainage structures
- Construction of additional airside access roads

Incidents

Considering that the construction took 17 months and, given the inherent high risk of undertaking airside work at an operational airport, there were only two (2) major incidents viz:

- A runway incursion occurred early in the construction stage during the rehabilitation of the taxiways. The incursion happened after a water truck driver (despite being under escort) lost his way and found himself on the threshold of runway 11 – this whilst an aircraft was waiting at the alpha taxiway holding point at runway 29!

  The escort vehicle fortunately saw event and immediately contacted the ATNS, who, in turn, alerted the pilot of the waiting aircraft. The offending vehicle was guided back to the site offices and the driver was removed from the project.

Whilst the incident did not have any real impact on airport operations, the consequences, had the escort vehicle not seen the event, could have been disastrous.

Following the incident, vehicles were guided by escorts not only in front, but also behind. Once work was completed on the taxiways, the possibility of construction vehicles/personnel coming into conflict with airport operations was nullified as access was only gained once the airport was closed for the night.

- The second incident involved a dozer driver who reversed his machine into the corner of the 11 ILS instrumentation building. The incident happened towards the end of the night shift and in cold, wet, weather.

  Whilst the building was damaged seriously enough to require immediate propping and some temporary brickwork, the instrumentation itself was not damaged and continued to operate correctly.

  Following this incident, it was decided to replace the two (2) ILS buildings with specially manufactured steel containers.

<u>Lessons Learnt</u>

When undertaking major construction on the airside of an operational airport, lessons are leaned almost daily. Some of the more important are summarised below:

- Have adequate numbers of Site Staff – whilst the consulting engineer had a full time Resident Engineer with supporting staff, it was often not enough to monitor all the works that were underway.
- Extended periods of pressurised night work, for the contractor’s personnel, was found to be the main cause of minor incidents such as damaging of airport services, vehicle collisions (refer above), and also affected the quality of the workmanship.

  On this project, the contractor worked a six (6) night week, Monday through Saturday and it is considered, that this is, based on experience, probably too much. Rather have a five (5) day week and a longer contract period
- The raising and lowering of levels in the controlled areas of the RESA (in front of the ILS instrumentation and glide path indicators) can affect the instrumentation. If major earthworks are unavoidable in these areas, the only option is to switch off the adjacent ILS until the works are complete and then undertake a re-calibration.
- Airside work must not even be attempted without nightly “start up” meetings. These were done on this project and incidents still occurred. Without such meetings, undertaking the work safely would be impossible.
- Community Liaison should be undertaken with neighbouring communities prior to construction commencing. On this project, whilst it was considered that all eventualities had been catered for, the one aspect that was forgotten was the issue of nightly construction “noise pollution” and disturbance to the residents of adjacent areas.

  The issue was brought to light within 6 weeks of the construction commencing when residents formed a committee and threatened to take legal action over unacceptable noise levels during the night. A meeting with affected parties was convened and the consulting engineer, in conjunction with ACSA management addressed the issue. Following this meeting, regular follow up meetings were held.

Whilst the community continued to endure noise during the night, they were at least aware of the reasons and kept informed on progress. The original unhappiness could have been avoided if liaison had been undertaken during the design stage.

Statistics

Some of the more important construction statistics are given below:

- Contract award value – R190M (AU$ 20M), final cost – R185M (AU$19M)
- Area of asphalt - 270,000 sq. m, 75,000 tonnes
- Mass earthworks – 64,000 cu. m
- Layerworks at RESA's – 22,000 cu. m
- Milling – 15,000 cu. m
- Line markings – 64 km
- Shaping and trimming 800,000 sq. m
- Gabions – 1,200 cu. m
- New electrical cabling/ ducting – 9,400 m

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