Aéroports de Montréal

RUNWAY 06R–24L REHABILITATION
Aéroport Pierre-Elliott-Trudeau

ENGINEERING BY:

CONCEPT AND TECHNICAL ANALYSIS :

Élie El Hindy, ing. M.Sc.A

Program :

1. Runway Location
2. Runway history
3. Technical analysis
4. Retained concept for tender
5. Final optimisation
6. Construction site
7. Miscellaneous

1. Location

1. Location Related taxiways

Related taxiways

2. History

The Runway was built in 1958

- 300 mm slab thickness without reinforcement
- 6.1m x 6.1m dimensions
- Macadam type material 300 mm of thickness
- 61m runway width including shoulders
- 2 940 m length

Major rehabilitation in 1983

- Replacement of fractured slabs
- 100 mm overlay using hot mix asphalt

2. Runway history

Observed degradation

- Thermal cracking
- Reflective joints and cracks
- Delamination of the asphalt layer
- Alligator cracking

2. Runway history

Runway shoulders degradation

2. Runway history

Repair cost since 10 years

- Patch repairs (asphalt) 2003
- Reflective joints sealing
- Slab repairs (partial and full depth repairs)
- 750 000 $ spent between 2001 and 2003
- Related problems: Instanteneous runway closing
- Very low PCI (pavement condition index)
- High risk of FOD (foreign object debris)
- Low PCN (pavement classification number)
- **RECOMMANDATION: Major rehabilitation is needed**

3. Technical analysis

Project criterias

- Adjust the longitudinal slope
- Adjust the transversal slope (1 and 1.5%)
- Rehabilitation of the drainage system
- Normalize the electrical system
- Finish the rehabilitation in 22 weeks
- Maintain access for Bombardier and regional activities at all time

3. Technical analysis

Technical solutions analysed

1. Take out the existing asphalt layer, repair fractured slab and put a new asphalt layer
2. Built a new rigid pavement on top of the existing composite pavement
3. Take out the existing asphalt layer, rubblizing the concrete slab and put a new asphalt layer

3. Technical analysis

1. Fractured slab replacement + asphalt layer on top

- Cost ± 17 M$
- Higher profil, need to built new transition with all related TWY
- High risque to discover more than expected fractured slabs (cost)
- Expected life before major rehabilitation 15 years
- Reflective joints not eliminated (5-8 ans)

3. Technical analysis

2. Rigid pavement on top of the existing composite pavement

- Cost ± 17 M$
- Higher profil, TWY transitions adjustement
- Better surface drainage of the RWY strips
- Slab size identical to the existing slabs
- Better friction index at the opening
- Life: 20 years

3. Technical analysis

3. Rubblzing + asphalt layer

- Cost estimate : ± 20 M$
- Tested in 2001 on TWY A3 (similar pavement structure)
- High risk of pavement failure during rubblization activities
- Non-uniform resilient modulus of fractured slabs
- Similar longitudinal profil
- Specialized contractor (2 known in USA)
- Life : 15 years

4. Retained solution

Rigid pavement on top of the existing composite pavement

5. Final Optimization

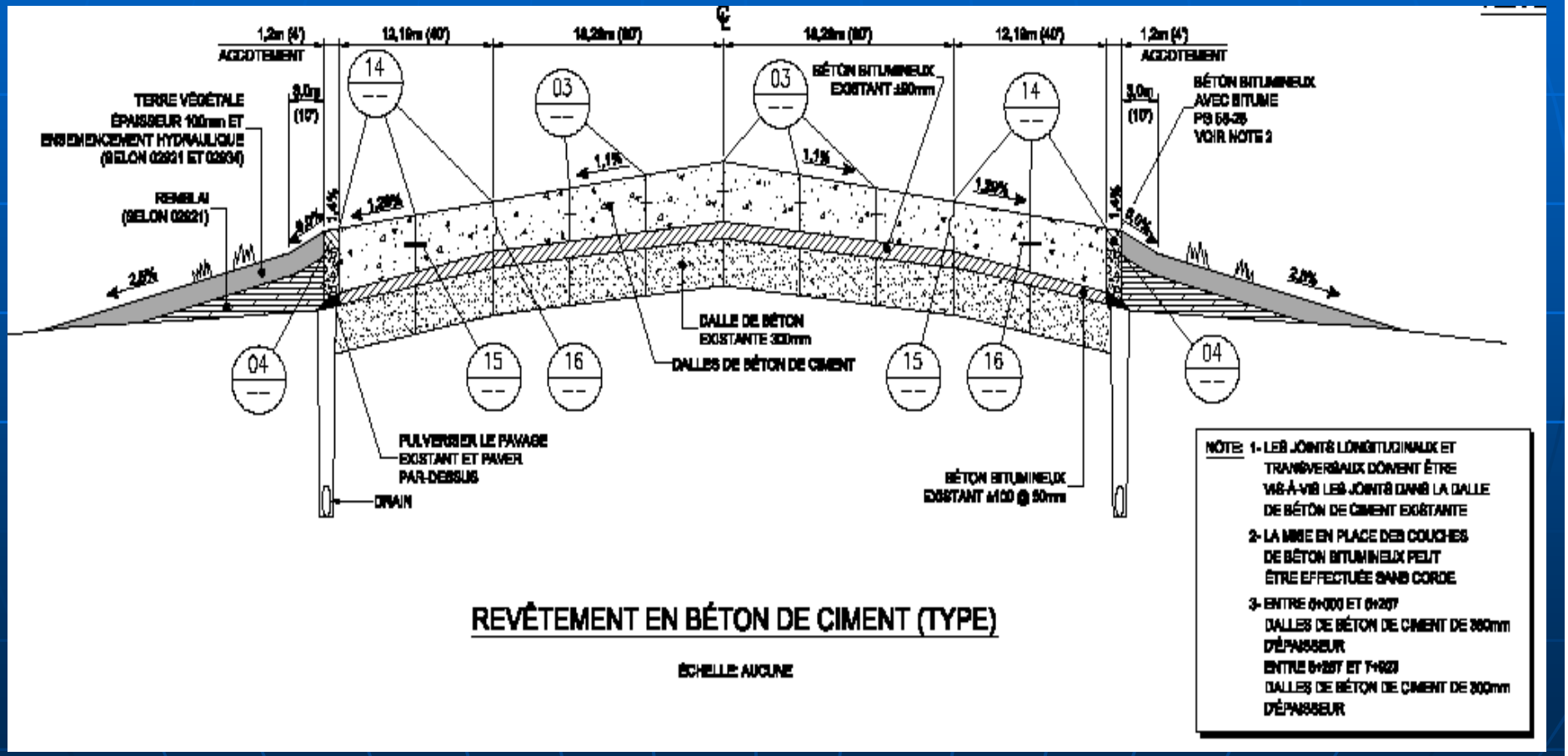
Optimization of the rigid pavement solution

- Centerline and exit section built with 4.5 MPa flexural strength concrete
- Sections outside the centerline built with 3.5 Mpa flexural strength concrete
- Hot poured sealant for the joints
- Transversal slopes of:

1.1% for the centerline section and 1.29% for all other sections

- Slab minimum thickness of 300 mm
- Rebuilt the TDZ at the 06R with 380 mm slab thickness.

5. Final Optimization



REVÊTEMENT EN BÉTON DE CIMENT (TYPE)

ÉCHELLE: AUCUNE

6. Construction site

First Step :

- Site preparation
- Concrete plant installation
- Demolition of the TDZ of the 06R (256 m)
- Build temporary roads to get access to the RWY

6. Construction site

Concrete plant installed on site

6. Construction site

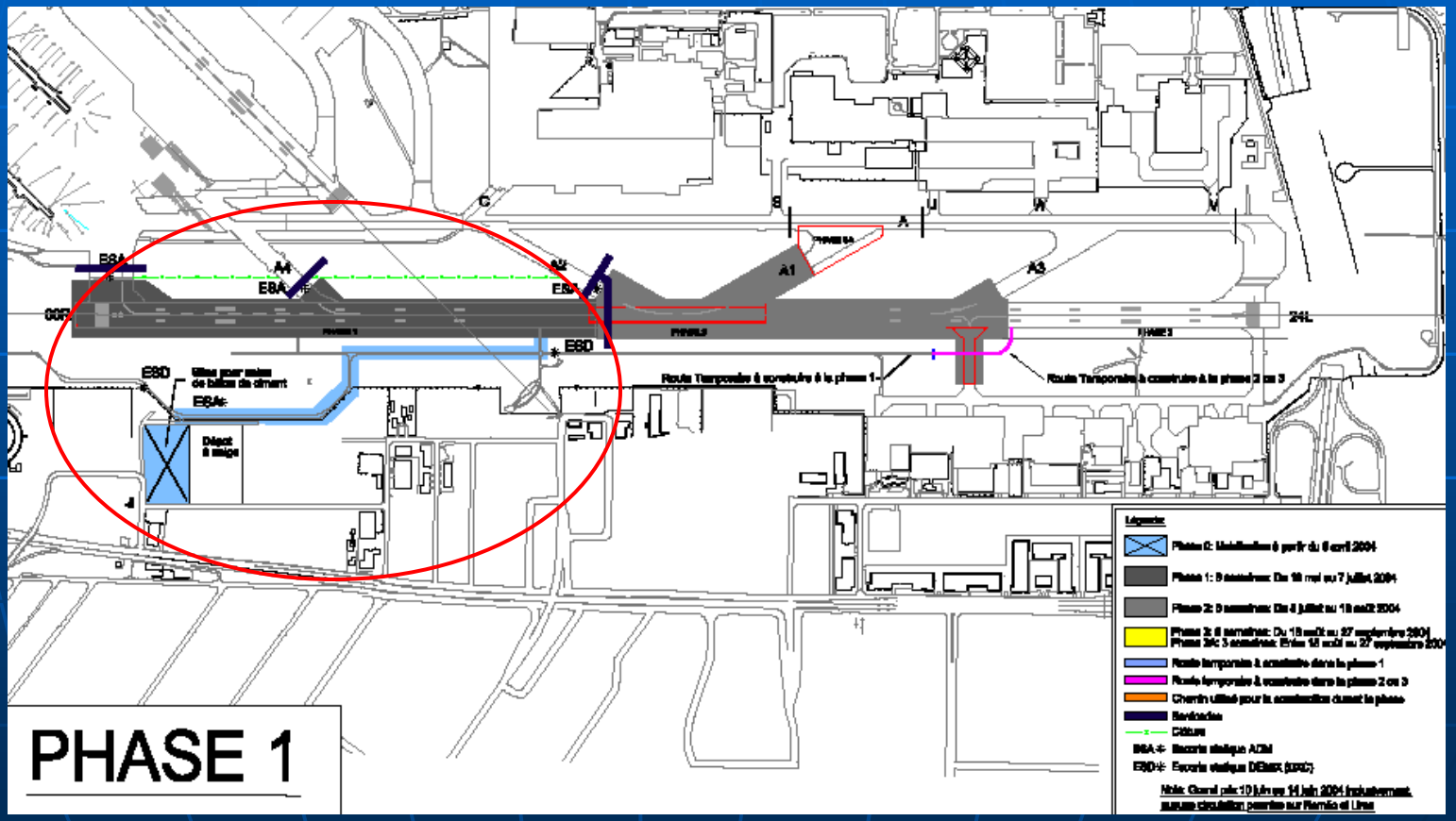
06R TDZ demolition (256 m)

6. Construction site

Start of concreting activities :

- Paving machine type GUNTER that can pave at least 6 m of slab width
- Dowels for load transfer at longitudinal joints
- Micro texturing using the astro-turf carpet (longitudinal direction)
- Macro texturing (grooving in fresh concrete) transversal direction
- Slab of 6m x 6m. Juxtaposed on top of the existing slab

6. Construction site

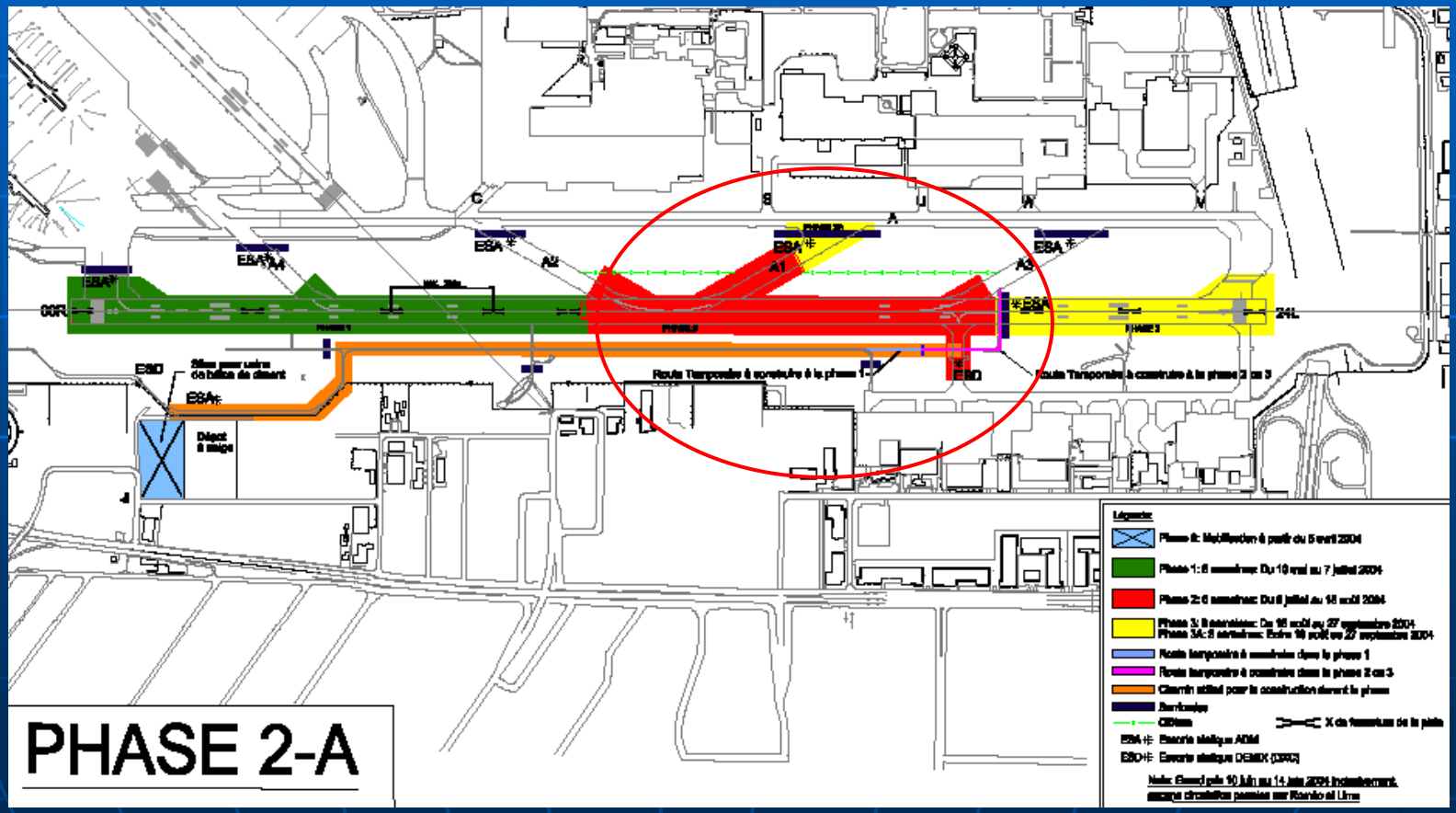


Phasing for allowing aircraft movements

6. Construction site

Phase 1

6. Construction site

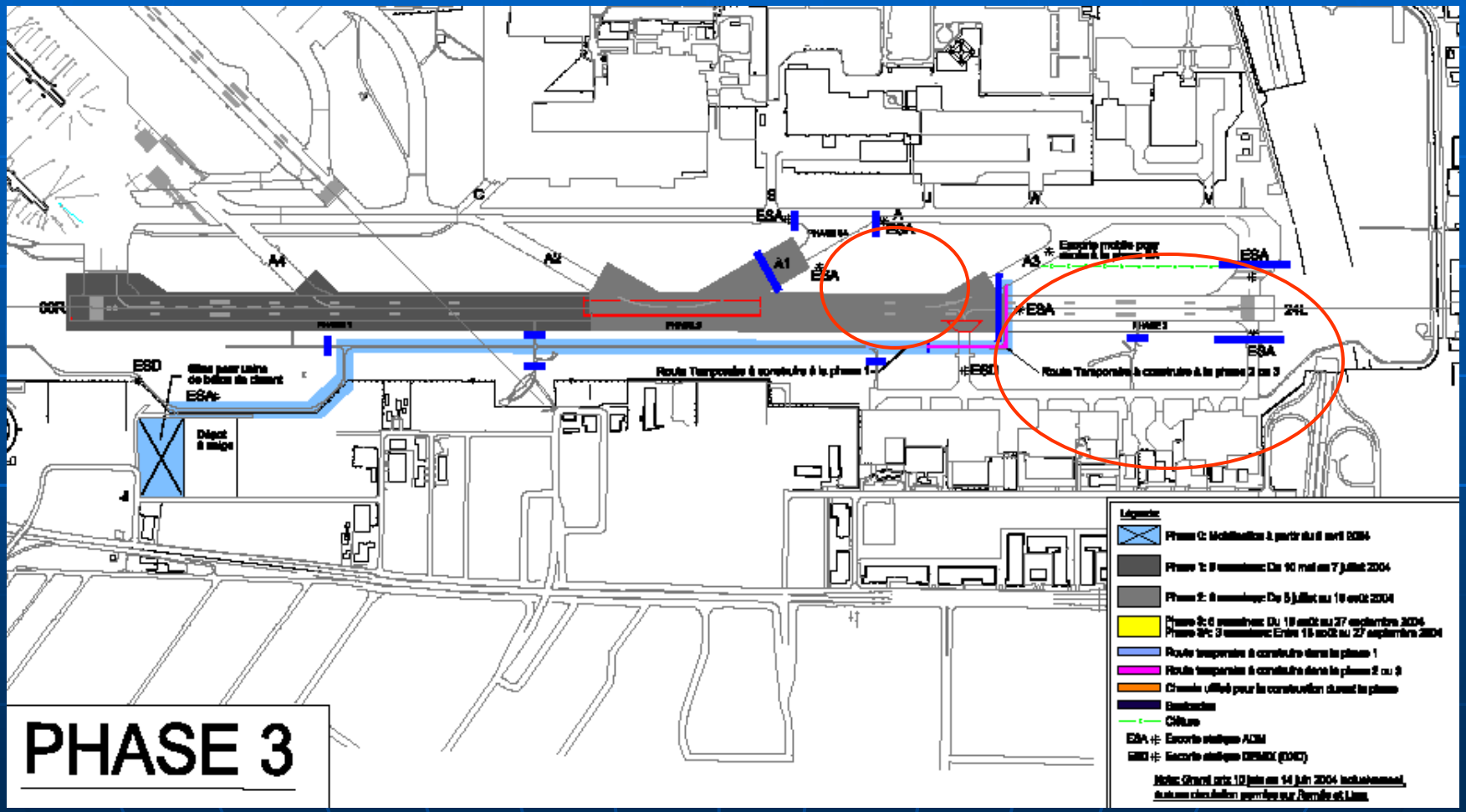


Phasing for allowing aircraft movements

6. Construction site

Phase 2

6. Construction site



Phasing for allowing aircraft movements

6. Construction site

Phase 3

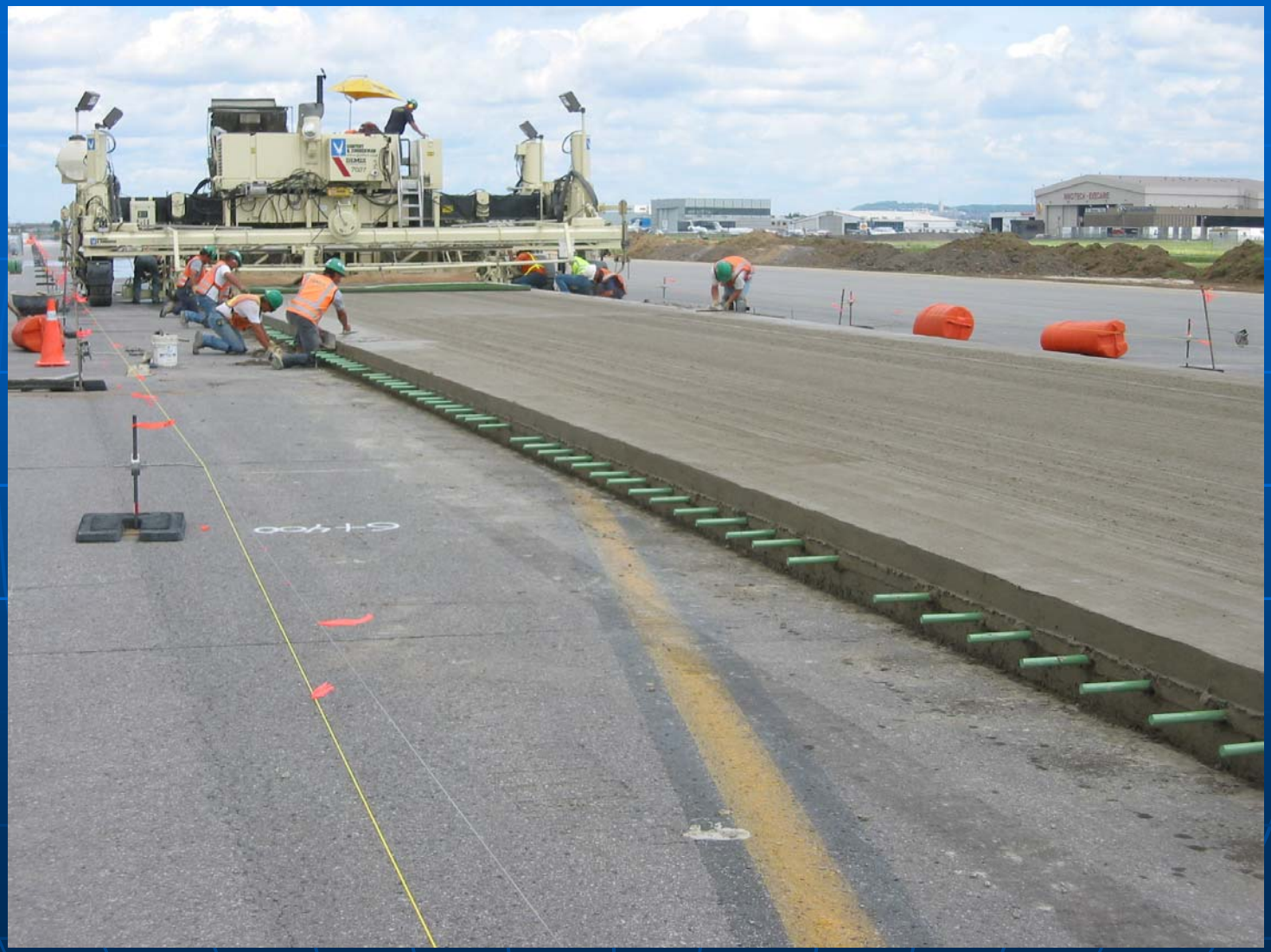
6. Construction site

Gunter paving machine

6. Construction site

Macro and Micro texturing

6. Construction site



Dowels installation during paving

6. Construction site

Shoulders paving (1.2 m)

6. Construction site

Paving the transitions with the TWY

6. Construction site

RETWY paving

6. Construction site

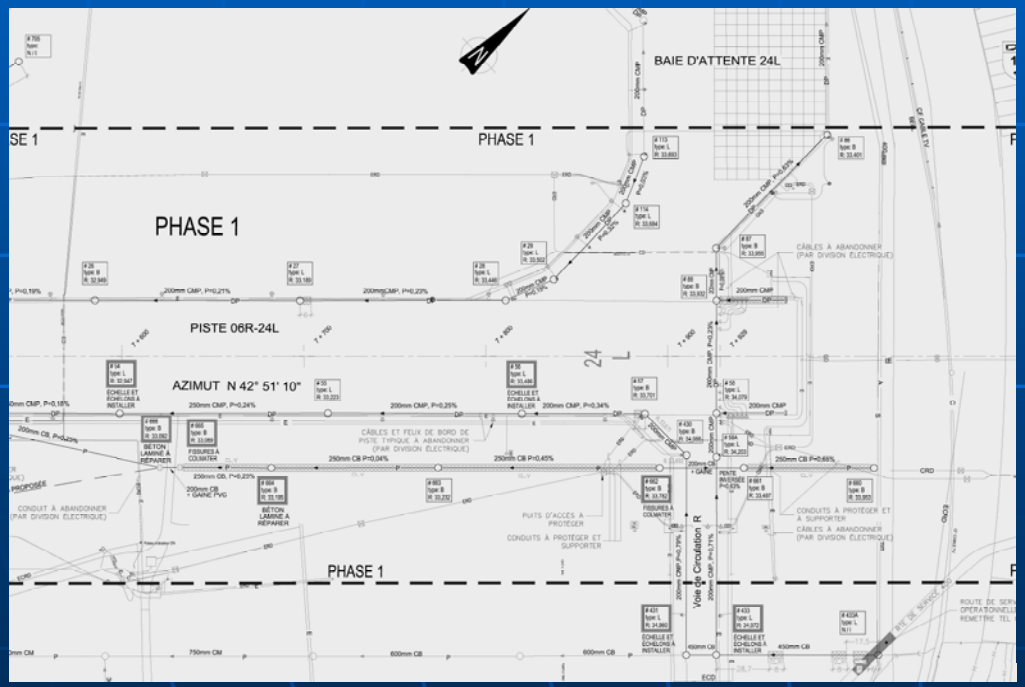
Water testing for slope verification

6. Construction site

Joint sealing activities

6. Construction site

Drainage work :



6. Construction site

Drainage problems

6. Construction site

Deficiencies correction:

- Cracks on the surface of the slabs
- Slabs affected by rain
- Joint Spalling
- Slopes and water ponds

6. Construction site

Macro/Micro texturing of the slab a surface affected by rain

Grinding the surface + adding new grooves

6. Construction site

Deficency caused by uncleaned concrete truck

6. Construction site

Depression at the longitudinal joint

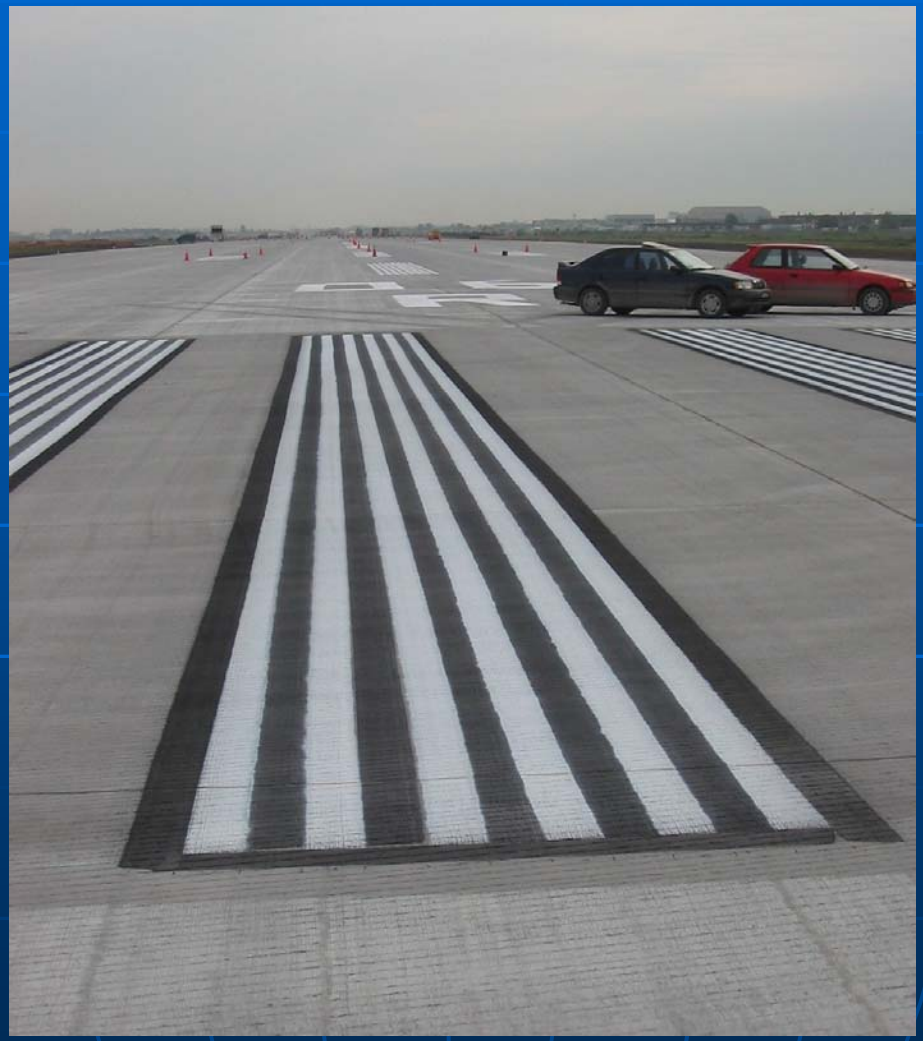
6. Construction site

Spall at the joint

7. Miscellaneous

- Marking
- Landscaping

7. Miscellaneous



Marking

7. Miscellaneous

Critical moment for concrete casting

7. Miscellaneous

Critical moment for the workers during threshold relocation

7. Miscellaneous

Critical moment caused by workers

Final result

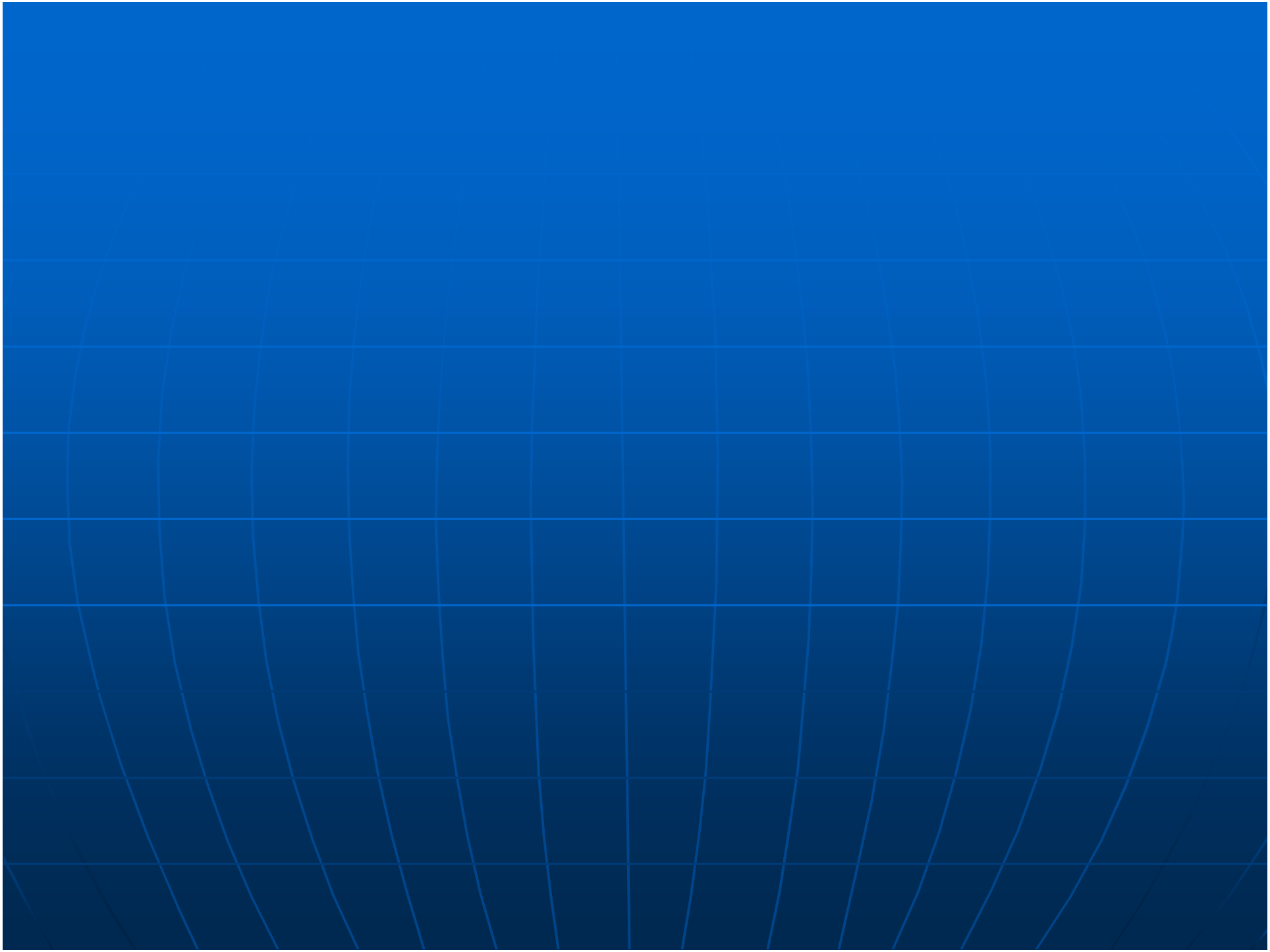
Final result

Statistics

- Concrete : 63 000 m3
- Asphalt : 15 000 t
- Sewers : 1000 m
- Top soil : 25 000 m3
- Granular material : 20 000 tons

Thank you for your attention

Questions ?



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CASE STUDY

THE USE OF A STABILIZED BASE WITH ASPHALT EMULSION AND CEMENT FOR THE REHABILITATION PROJECT OF THE 06L-24R RUNWAY

MONTREAL-TRUDEAU INTERNATIONAL AIRPORT - DORVAL

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November 1999

Updated : September 2011

REHABILITATION PROJECT OF THE 06L-24R RUNWAY AND HOLDING BAYS, MONTRÉAL-TRUDEAU

TERRITOIRE AÉROPORTUAIRE - *SÛRETÉ / AIRPORT TERRITORY - SECURITY*

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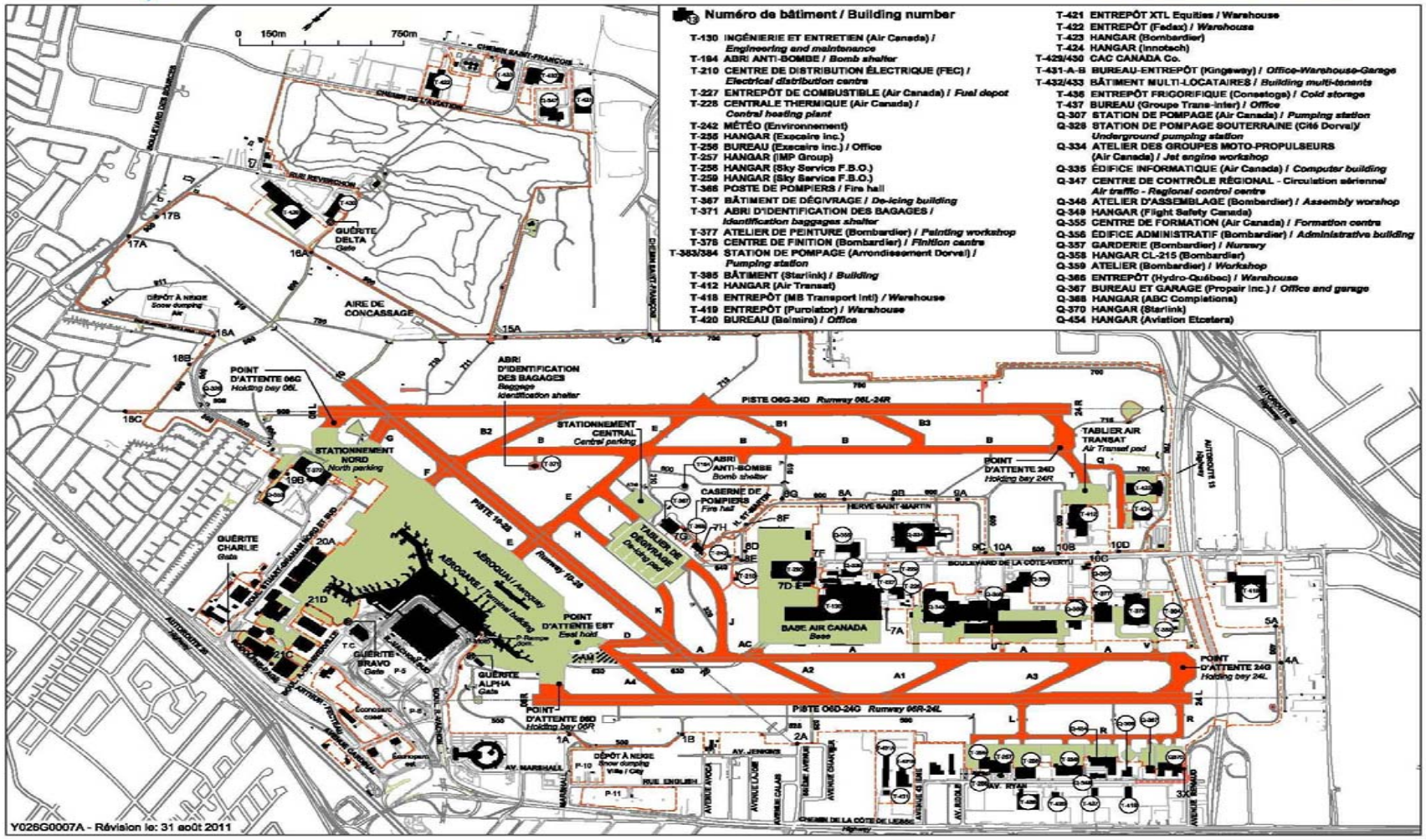
AIRES DE MANOEUVRE / *Manoeuvring areas*

AIRES DE TRAFIC / *Aprons*



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REHABILITATION PROJECT OF THE 06L-24R RUNWAY AND HOLDING BAYS, MONTRÉAL-TRUDEAU

PHYSICAL CHARACTERISTICS OF THE 06L-24R RUNWAY

CONSTRUCTION	1941
REHABILITATION / EXTENSION	1951, 1960, 1962, 1970, 1982
LENGTH	3353 m
WIDTH	62 m
STURCTURAL COMPOSITION	1200 m SIDE 24r : bituminious concrete/concrete slab/macadam 2153 m SIDE 06l : bituminious concrete/macadam
NATURAL LAND	Till/clay
WATER TABLE	±1,5 m deep

PHYSICAL CHARACTERISTICS OF THE HOLDING BAYS

CONSTRUCTION	1960, 1970
STRUCTURAL COMPOSITION	300mm concrete slab, 6 m X 6 m without dowells over macadam

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REHABILITATION PROJECT OF THE 06L-24R RUNWAY AND HOLDING BAYS, MONTRÉAL-TRUDEAU

STATE OF THE CURRENT INSTALLATIONS

CIVIL

- index of surface condition (PCI) < 70 by area
- high risk of FOD
- PCN index > ACN index (track, bay 06)
- PCN index < ACN index (bay 24)
- transverse slope< 1 %
- poor drainage of adjacent surfaces
- some clogged culverts
- Category 2 runway

ELECTRICAL

- Old electrical wiring imbedded in asphalt concrete
- Primary and secondary cables in ground, not protected
- Insulation resistance of the distribution cables < 6 MOhms
- Old and damage embedded lighting pods

REHABILITATION PROJECT OF THE 06L-24R RUNWAY AND HOLDING BAYS, MONTRÉAL-TRUDEAU

SCOPE OF WORK

- Rehabilitation of the runway surface course
- Rehabilitation and reinforcement of the concrete holding bays
- Rehabilitation of the drainage works
- Correction of the adjacent landscaping
- Marking
- Reconstruction of the electrical system
- Reconstruction of the lightning system

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REHABILITATION PROJECT OF THE 06L-24R RUNWAY AND HOLDING BAYS, MONTRÉAL-TRUDEAU

REHABILITATION OPTION OF THE TRACK

GOALS

- The shortest possible construction schedule
- A minimum investment cost for a better lifespan
- A design that helps and reduces maintenance costs
- The traffic characteristics
- The actual and predicted use o the runway
- Protection of the environnement and recycling of materials on place

OPTIONS (Stage planning)

- Resurfacing with asphalt concrete : 10 years ; work over a 7 week span ; construction cost : ±6,6 M$ (1997$)
- New coating with asphalt concrete on a stabilized based foundation ; +/-20 years ; works over an 11 week span ; construction cost : ±8,1 M$ (1997$)
- New coating with cement concrete ; +/-25 years ; works over a 15 week span ; construction cost : ±12,9 M$

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REHABILITATION PROJECT OF THE 06L-24R RUNWAY AND HOLDING BAYS, MONTRÉAL-TRUDEAU

SELECTED OPTION (CIVIL)

RUNWAY

- New pavement with 125mm asphalt concrete
- Stabilized base 200 mm with existing materials
- (75 % cement concrete, 25 % asphalt concrete) in the central section of 30m ;
- Shoulder : crushed stone 0-40 mm
- Stabilization with 2,8-3,0 % of added bitumen and 1,2-1,5 % cement
- midland batching plant on site
- same geometry

HOLDING BAY

- New concrete pavement, 380 mm, 6m X 6m with dowels

In both cases, the existing granular base 0 - 50 mm (macadam) is preserved.

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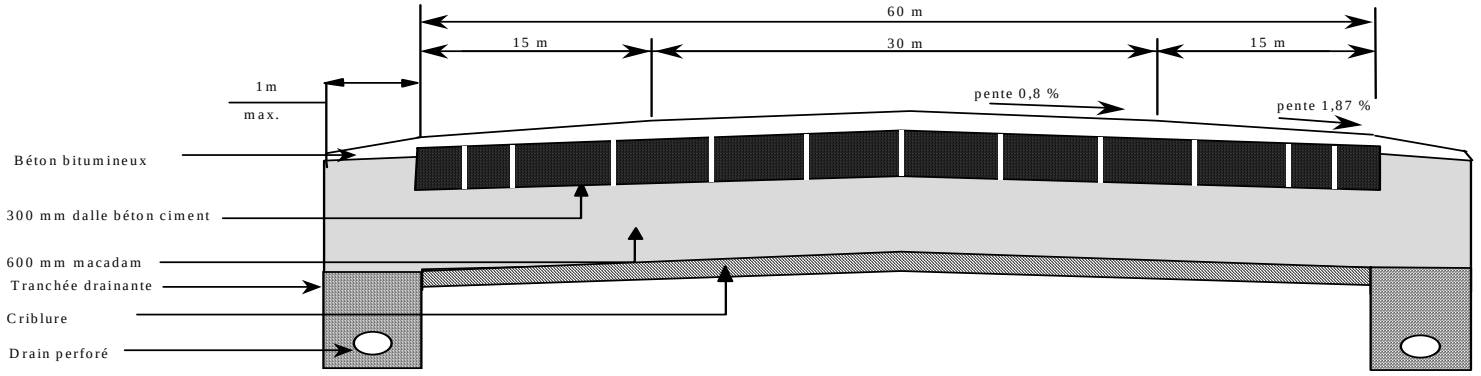
REHABILITATION PROJECT OF THE 06L-24R RUNWAY AND HOLDING BAYS, MONTRÉAL-TRUDEAU

SELECTED OPTION (ELECTRICAL)

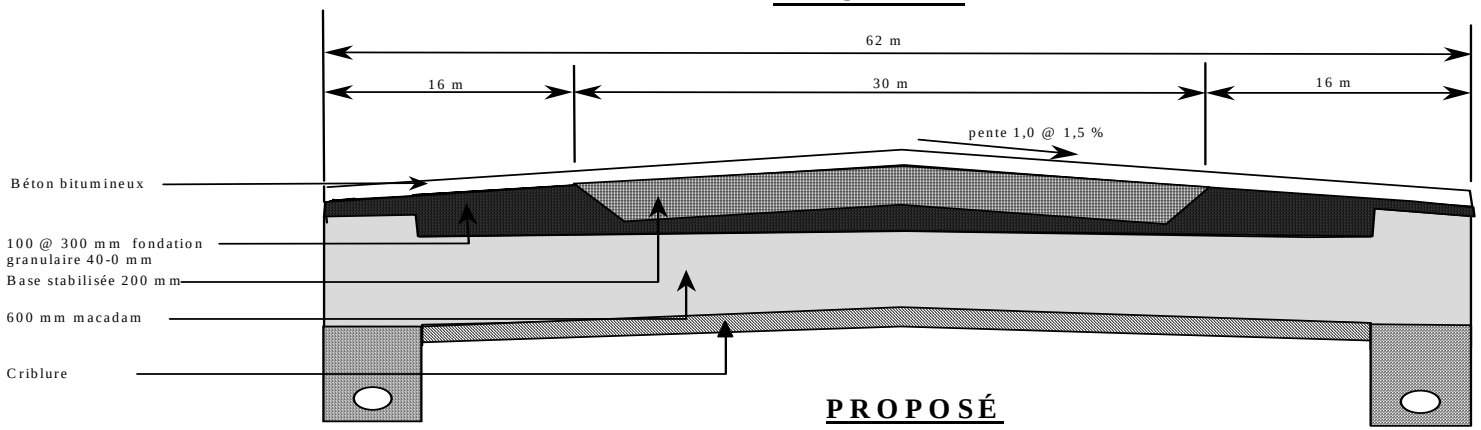
- SYSTEM REQUIREMENTS FOR SAME LIGHTNING INSTALLATIONS
- INSTALLATION OF THE TRANSFORMERS UNDER EMBEDDED LIGHTS IN PODS
- ELECTRICAL WIRING INSTALLED IN CONCRETE DUCTS UNDER THE STABILIZED BASE

REHABILITATION PROJECT OF THE 06L-24R RUNWAY AND HOLDING BAYS, MONTRÉAL-TRUDEAU

FIGURE 2a: coupe typique piste 06G-24D **(sur 1200m à partir du seuil 24D)**



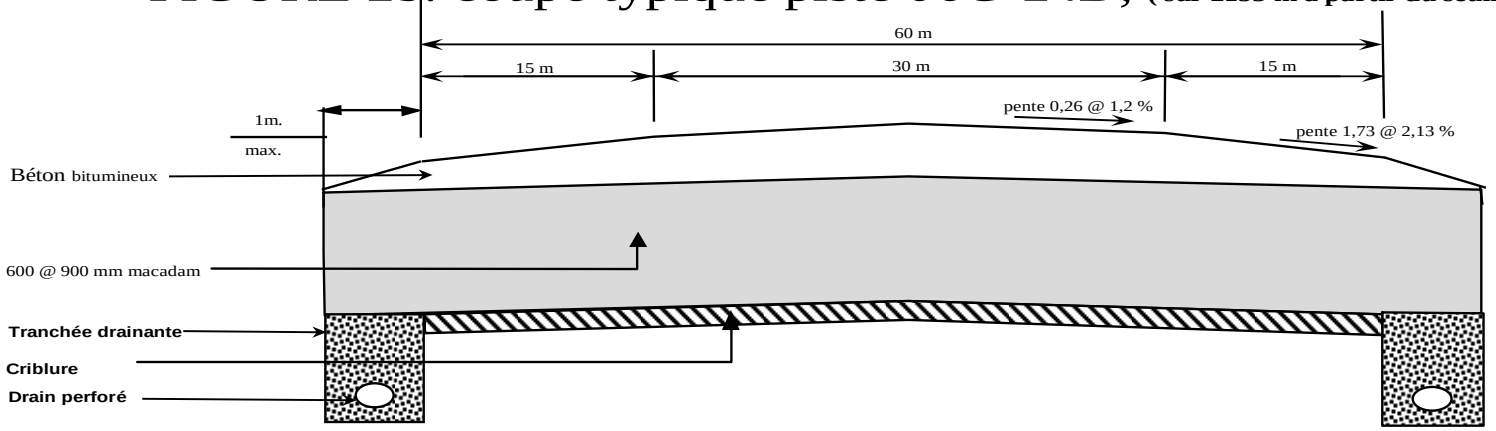
EXISTANT



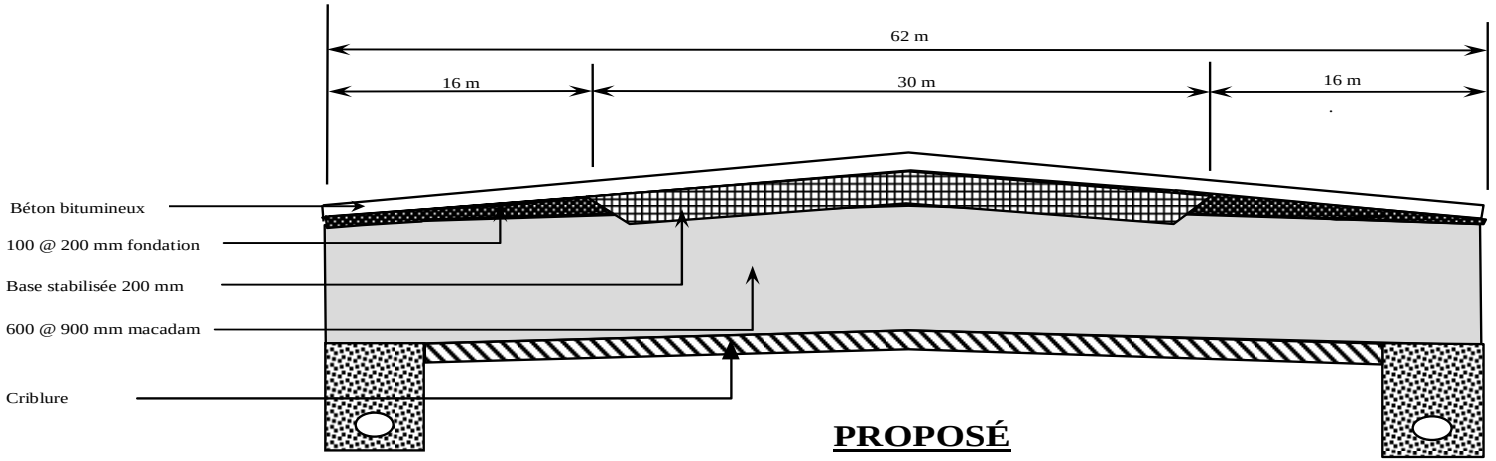
PROPOSÉ

Nouveau revêtement flexible avec base stabilisée

FIGURE 2b: coupe typique piste 06G-24D, **(sur 2153 m à partir du seuil 06G)**



EXISTANT



PROPOSÉ

Nouveau revêtement flexible avec base stabilisée

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REHABILITATION PROJECT OF THE 06L-24R RUNWAY AND HOLDING BAYS, MONTRÉAL-TRUDEAU

WORK PROCEDURES

Partnering (contractor, consultants, ADM)	• Common comprehension • Improved energy • Trust worthyness
Work realization / in 3 steps	• 1997 phase I (5 weeks), holding bay 24r and track on 1300m • 1998 phase II (5 weeks), holding bay, 06l and runway on 1400m • phase III (4 weeks), intersection runway 10-28 with 06l-24r on 600m, displaced threshold runway 06l
Demolition and removal of materials	• Concrete cement : percussion • Asphalt concrete : cold milling (±150 mm) • Preserve the integrity of the existing macadam (0-2'' granular base)
Crushing	• Crushing of the concrete pavement • Crushing and screening of the asphalt concrete

REHABILITATION PROJECT OF THE 06L-24R RUNWAY AND HOLDING BAYS, MONTRÉAL-TRUDEAU

- Combination 75 % cc/25 % ac **(ref. table 2)**
- Cbr ±75 % **(ref. table 4)**
- Stockpilling and protection of the crushed material (control of the water content)

TABLE 1
Average seive analysis results of crushed materials to be recycled in the stabilized base

Seive	Crushed concrete cement (cc)	Crushed asphalt concrete* (ac)	Combined Materials (75 % cc and 25 % ac)	Requirements
Seive (mm) 28	100	100	100	100
14	85	93	83	68 - 93
5	47	48	44	35 - 60
1,25	25	15	21	19 - 38
0,315	12	2	9	9 - 17
0,08	5,2	0,4	3,1	2 - 8

*crushed and screened

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REHABILITATION PROJECT OF THE 06L-24R RUNWAY AND HOLDING BAYS, MONTRÉAL-TRUDEAU

TABLE 2
Test result CBR on mixtures of concrete cement (BC), crushed asphalt concrete (EB) with or without stone screening 0-6 mm (CP)
(56 hits/layer, 96 hours of immersion)

	% of Test Mixtures				
Tests	65 BC ** 25 EB 10 CP	75 BC ** 25 EB	65 BC ** 35 EB	55 BC ** 45 EB	75 BC * 25 EB
CBR 0,1 po, %	93,3	47,7	42,2	25,8	55
CBR, 0,2 po, %	108,9	64,9	47,1	34,9	75
Expansion, %	0,19	0,18	-0,06	0,39	0,03
Density, kg/m cube	1930	1964	1934	1946	2018
Humidity, %	9,3	9,4	9,8	8,9	9,1

* Crushed samples on site by the contractor
** Crushed samples in the lab

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REHABILITATION PROJECT OF THE 06L-24R RUNWAY AND HOLDING BAYS, MONTRÉAL-TRUDEAU

WORK PROCEDURES

Granular base	Reshaping, resurfacing and compaction **(ref. table 3)**
	Preserve the integrity of the macadam
	Tack coat
	Emulsion css-1 diluted (stabilized base)
	Cutback rm-20 (granular)

Stabilized base	**Mix of crushed materials 75 % bc/25 % bb**
	Emulsion or ciment proportions :
	2,8-3,0 % (emulsion css-1) residual asphalt content
	1,2-1,5 % cement **(réf. tableau 4)**
	Mixing at the midland plant:
	Segregation control
	Water content control
	Optimisation of aggregate coating
	Quality control **(ref. table 5)**

TABLE 3
Average caracteristics of the existing granular foundations (0 - 40)

Gradation and physical properties	Specifications	Crushed stones * 40 - 0 mm	Macadam *
Tamis (mm) 50	100	100	98
37,5	70 - 100	95	82
19	50 - 75	70	45
9,5	40 - 65	46	34
4,75	30 - 50	33	27
0,425	10 - 30	12	11
0,075	3 - 7	6,3	4,8
0,02	< 3,0	3,8	3,4
Los Angeles (grade A)	< 50	30 %	
Micro-Deval (grade B)	< 33	20 %	
Organic materials	< 0,8	0,09 %	
Fragmentation pourcentage	100%	100 %	100 %
Petrographic number	< 200	115	
$MgSO_4$	< 20	12 %	

* Samples taken after final compaction

TABLE 4
Technical requirements for a stabilized base

Gradation	Requirements	Formula
28	100	100
14	68 – 93	81
5	35 – 60	47
1,25	19 – 38	24
0,315	9 – 17	10
0,080	2 – 8	4,8
Added asphalt content %	3,00 minimum	2,8 *
Marshall stability, N	10 000 minimum	13 880
Flow, mm	2-4	3,7
Bearing capacity, MPa according to Metcalf	1,0 minimum	1,55
Selected stability, %	80 minimum	92,2
Coating, %	90 minimum	90
Marshall density, kg/cm³		2,002
Cement %	1,5 maximum	1,2 - 1,5**
Water optimum	+ 0 %, - 1 %	6,0

* After the first trial sections, asphalt content was adjusted at 2,8 %
**1,2 % cement for phase I raised to 1.5% for phases II and III

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REHABILITATION PROJECT OF THE 06L-24R RUNWAY AND HOLDING BAYS, MONTRÉAL-TRUDEAU

TABLE 5
Result compilation – Stabilized base

Gradation and Physical properties	Specifiations	Formula	Phase I Average value	Phases II - III Average value
Sieves (mm) 28	100	100	100	100
14	68 – 93	81	78	84
5	35 – 60	47	42	44
1,25	19 – 38	24	21	21
0,315	9 – 17	10	9	9
0,080	2 – 8	4,8	3,6	2,8
Content of residual bitumen		4,15	4,00	4,38
Added bitumen content	3,0 minimum	2,8	2,87	2,99
Marshall stability, N	10000 minimum	13880	11170	10752
Flow, mm	2 - 4	3,7	3,3	3,4
Bearing capacity, MPa according to Metcalf	>1,0	1,55	1,43	1,33
Selected stability, %	80 minimum	92,2	89,1	83,1
Coating %	90 minimum	90,0	88	88
Marshall density, kg/cm^3		2,002	2,002	2,000
Water optimum		6,0	7,1	8,3

Note : Emulsion CSS-1

WORK PROCEDURES (continuation)

Stabilized base	Trial section
	Curing time
	Pourcentage of added cement
	Water content of the mixture
	Weather conditions **(table 6)**
	Installation
	Levelling referencing mark
	Bin truck, mechanical ram and grader
	Compaction
	Curing (3 to 5 days)
	Plate testing for modules, e > 1,000 MPa à 10 hz

TABLE 6
Module (10 Hz) and deflexion versus curing (phase I)
loading plate testing, 300 kPa pressure-
Stabilized base placed in a single layer 200 mm

Results	Curing, days	
	One to three days	Four to five days
Number of tests	33	18
Average temperature °C	18	24
Average module, MPa	890	1280
Minimal module, MPa	323	609
Maximum module, MPa	2429	2940
Deflexion 1 in mm/5 minutes	0,42	0,31
Deflexion 2 in mm/5 minutes	0,15	0,14

TABLE 7
Module (10 Hz) and deflection versus curing (phases II and III) - Load plate testing, pressure of 300 kPa -
Stabilized base placed in a single layer of 100 mm of thickness

Results	Duration of the cure, days	
	One to three days	Four to five days
Number of tests	9	37
Average temperature °C	25	22
Average module, MPa	1120	1460
Minimal module, MPa	407	689
Maximum module, MPa	2381	2572
Deflection 1 in mm/5 minutes	0,27	0,27
Deflection 2 in mm/5 minutes	0,12	0,12

WORK PROCEDURES (continuation)

Bituminous concrete	Bitumen 120-150 (pg 58-28) phase I et II and bitumen polymère (pg 58-34) phase III
(Table 8)	Bitumen pourcentage
	Base : 4,8 % min.
	Surface : 5,6 % min.
	Conventional Installation
	Control on the joints overlapping
	Verification of the compaction by nucléodensimètre et carottage
Verification of the bearing capacity (Table 9)	Essais de plaque (french method)
	DCP tests and poinçon CBR
	Tests au déflectomètre lourd (hfwd)

TABLE 8
Technical requirements of asphalt mixtures

Seives	Requirements Base layer	Requirements Surface layer
25	100	
12,5	70 – 85	100
4,75	40 – 65	55 – 75
2,00	30 – 50	35 – 55
0,425	15 – 30	15 – 30
0,180	5 – 20	5 – 20
0,075	3 – 8	3 – 8
Asphalt content %	4,8 minimum	5,6 minimum
Voids %	2 – 4	2 – 4
VMA	13	15
Stability Marshall, N	9000 minimum	9000 minimum
Flow, mm	2 – 4	2 – 4
Asphalt grade*	120-150	120-150
Stability after immersion	75% min.	75% min.

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REHABILITATION PROJECT OF THE 06L-24R RUNWAY AND HOLDING BAYS, MONTRÉAL-TRUDEAU

TABLE 9
Bearing tests on site

Testing and test standards	Plate diameter and pressure	Test location
CBR test on the surface ASTM D-4429		Surface's stabilized base
DCP test on site Australian standard		Surface's stabilized base
Static plate load test	450 mm 300 kPa	Granular base foundation
Static plate load test	450 mm 300 kPa	Stabilized base at different degrees of curing
Deflection and rebound	450 mm 300 kPa	Stabilized base at different degrees of curing
Deflection and rebound	450 mm 628,7 et 301,8 kPa	Asphalt pavement base layer
Deflection and rebound	150 mm 1379 kPa 5092 kPa maximum	Asphalt pavement surface
Heavy falling wright deflectometer (HFWD) (ASTM-D4694)		Asphalt pavement surface

(1) Static plate load tests, operation mode CT-2 central lab of the bridges and pavements, Dunod, Paris, 1973
Drawn from the LVM Tech report, December 1998

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WORK PROCEDURES (continuation)

Bearing capacity verification	Comparison of the resilient modules E **(table 10)**
	Granular : e plate ≈ e hfwd, ± 250 à 280 MPa ;
	Base : e plate ≈ e hfwd, 1000 à 1100 MPa (short term) ;
	Base : e hfwd grows with time, 25 % in 3 months ; 60 % in 10 months ; 136 % in 23 months
	Base : e hfwd shoulder ≈ stabilized base (at the beginning).
Portland cement concrete (table 11)	New slab of 380 mm with dowel
	Cement type 20, u/c max. : 0,40
	Flexural strengh 5 MPa minimum
	Pouring concrete with concrete mixer and fixed fromwork
	Humid curing and chemical curing product
	Joint sealing with vulkem 202

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REHABILITATION PROJECT OF THE 06L-24R RUNWAY AND HOLDING BAYS, MONTRÉAL-TRUDEAU

TABLE 10
Structural parameters of the pavement, phase I
Runway 06L-24R, Dorval

STATIC LOAD PLATE TEST							
Structural layers	**thickness**	**Design parameters**	**(construction)**	**tests HFWD (July 98)**	**tests HFWD (sept. 98)**	**tests HFWD (Mai 99)**	**tests HFWD (Mai 00)**
		elasticity modules (à 25 °C)	elasticity modules ±25 °C	elasticity modules ±25 °C	elasticity modules ±25 °C	elasticity modules ±25 °C	elasticity modules ±25 °C
bituminious concrete	125 mm	1380 MPa	-------	1400 MPa	1400 MPa	1400 MPa	1400 MPa
stabilized base	200 mm	1034 MPa	1000-1280 MPa	1100 MPa	1400 MPa	1750 MPa	2600 MPa
granular base	600 mm	310 MPa	250 MPa	280 MPa	300 MPa	350 MPa	380 MPa
ground sub base	-----	110 MPa	250 MPa	270 MPa	280 MPa	340 MPa	320 MPa

TABLE 11
Technical specifications for the cement concrete mixture

PHYSICAL PROPERTIES	SPECIFICATIONS
air content	5 to 7 %
Slump *	60 à 100 mm
Flexural strenght 7 days 28 days**	 3,5 MPa minimum 5 MPa minimum
Concrete temperature	26 °C maximum
Spacing factor	Inferior to 230 µm

* Pouring concrete with fixed formworks
** Average value of two samples

NOTE : cement type 20, W/C max. ratio 0,40
aggregates 100 % crushed, 28-5 mm.

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PRELIMINARY CONCLUSIONS FOR STABILIZED BASE (WINNING CONDITIONS)

- An enforces quality control during the manufacturing and construction
- A quality control thightened at the manufacturing and during the installation
- An experienced and organized contractor
- An optimized proportuning of constituance and water content as well
- Good batching plant
- A proper spreading and compaction of materials
- Multiple leveling references
- Time of the year as weather is important
- Follow-up and performance check for runways 06l-24r in 20m