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ADVANCED, MODERN AND INNOVATIVE TECHNOLOGIES USED AT THE HOUSTON AIRPORT SYSTEM

(Pavement Surfaces)

By

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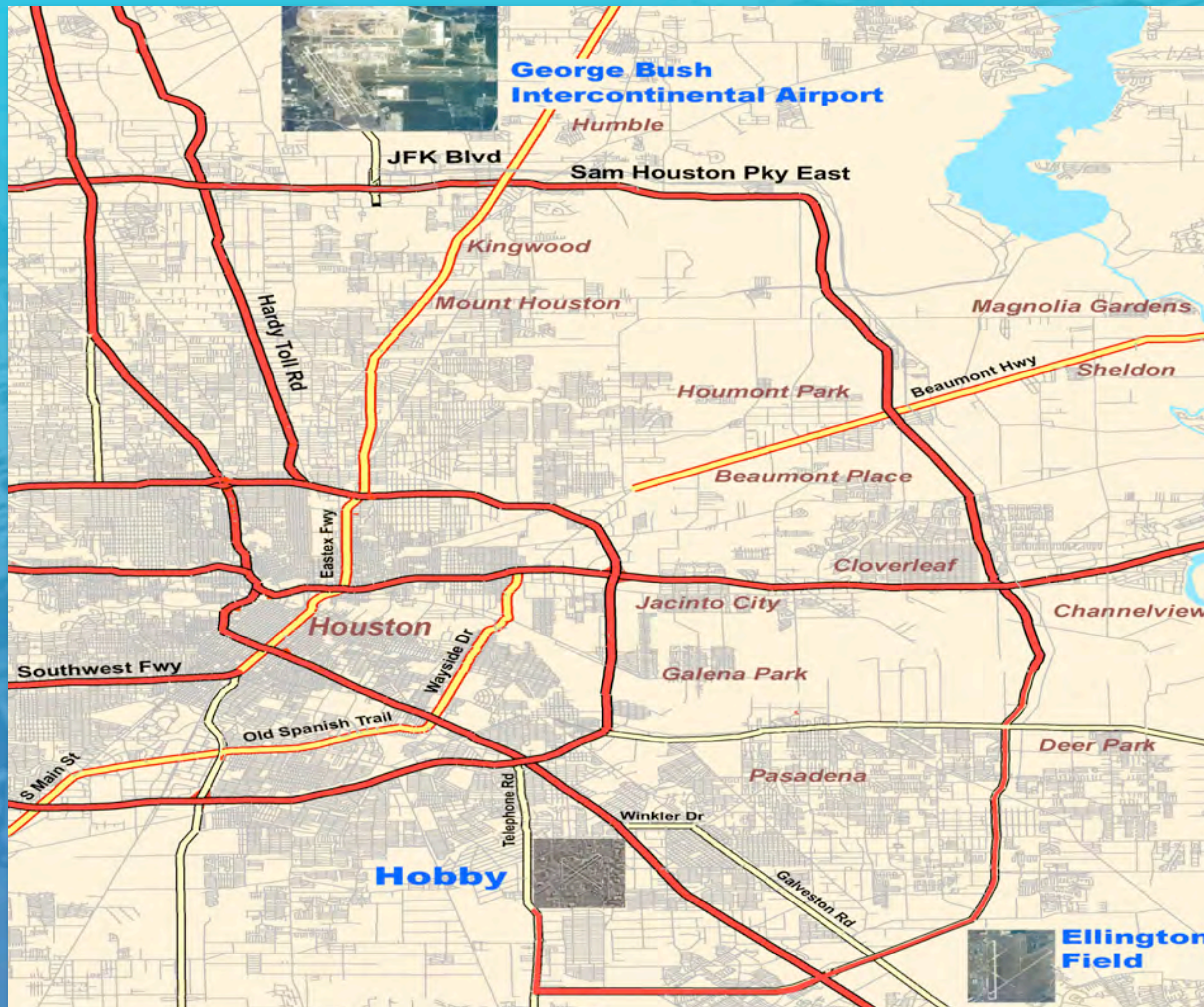
GEORGE BUSH INTERCONTINENTAL AIRPORT LOCATION



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555 Aerial

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NOVAPHALT HOT MIX ASPHALTIC CONCRETE (POLYETHYLENE ADDITIVE)

Novophalt Asphalt improves the following properties of theHot Mix Asphaltic Concrete

1. Better Viscosity
2. Improvement in Temperature Susceptibility
3. Higher Marshall Stability
4. Higher Modules of Elasticity
5. Higher Tensile Strength
6. Better Moisture Resistance
7. Better Fatigue Resistance
8. Better Resistance to Permanent Deformation
9. Better dynamic modules, creep resistance, resilient modules, Flexural modules
10. Less Damage to Pavement
11. Less Rutting
12. Less Cracking

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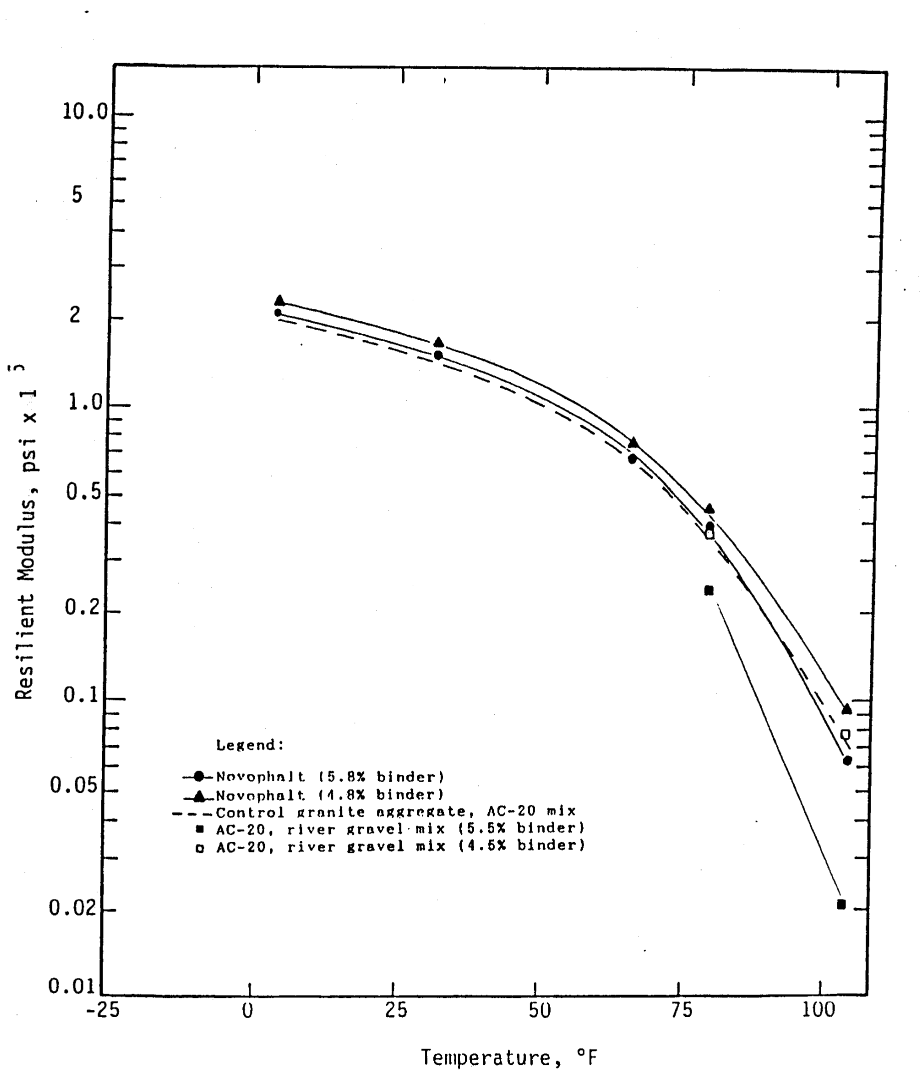

Figure 11. Resilient Modulus Versus Temperature Relationships for Novophalt Mixture Groups (5.8 and 4.8 percent binder) and for Traditional Mixtures Using AC-20 Asphalt Cement without Polyeythelene.

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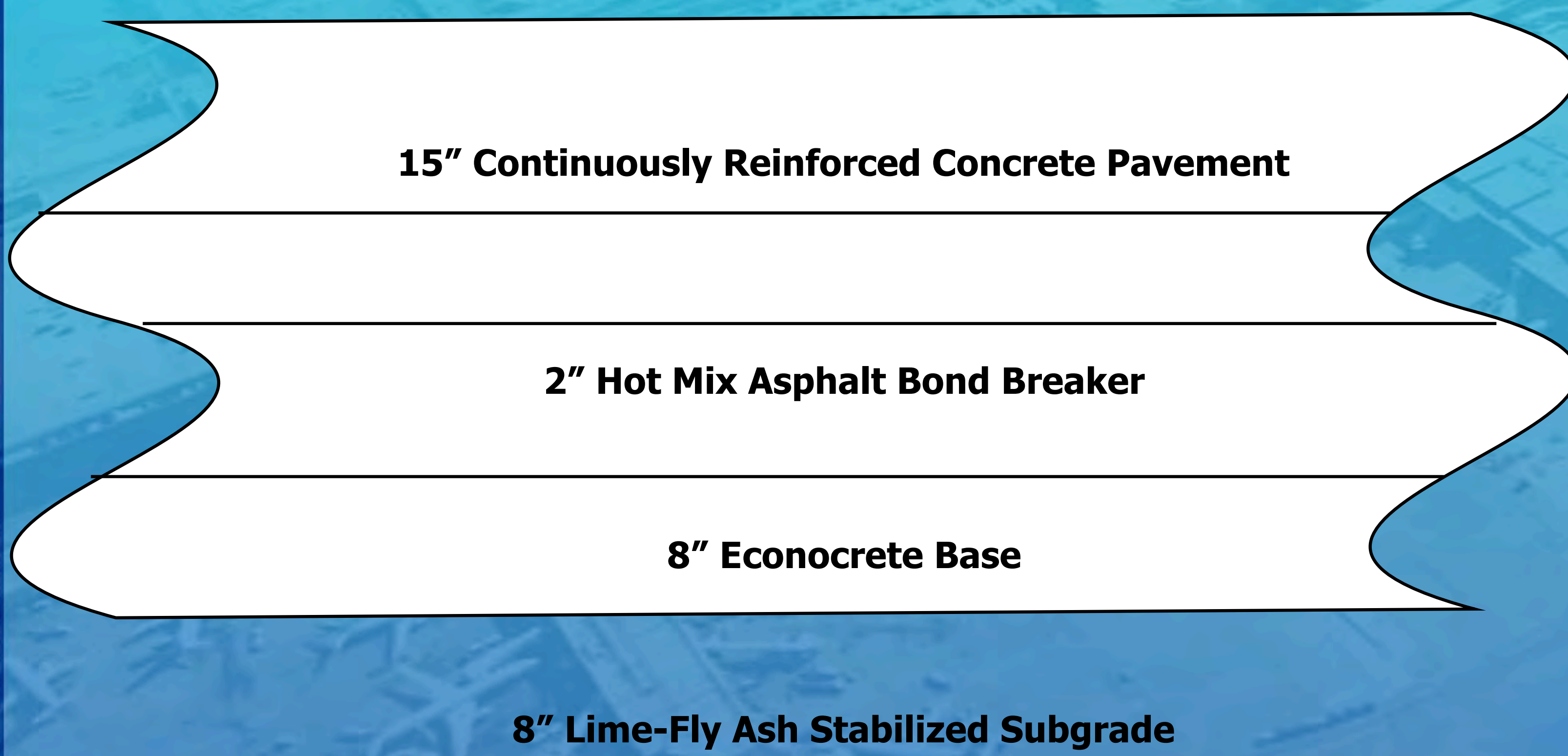
PAVEMENT CROSS SECTION FOR RUNWAY 4-22 AT HOBBY AIRPORT



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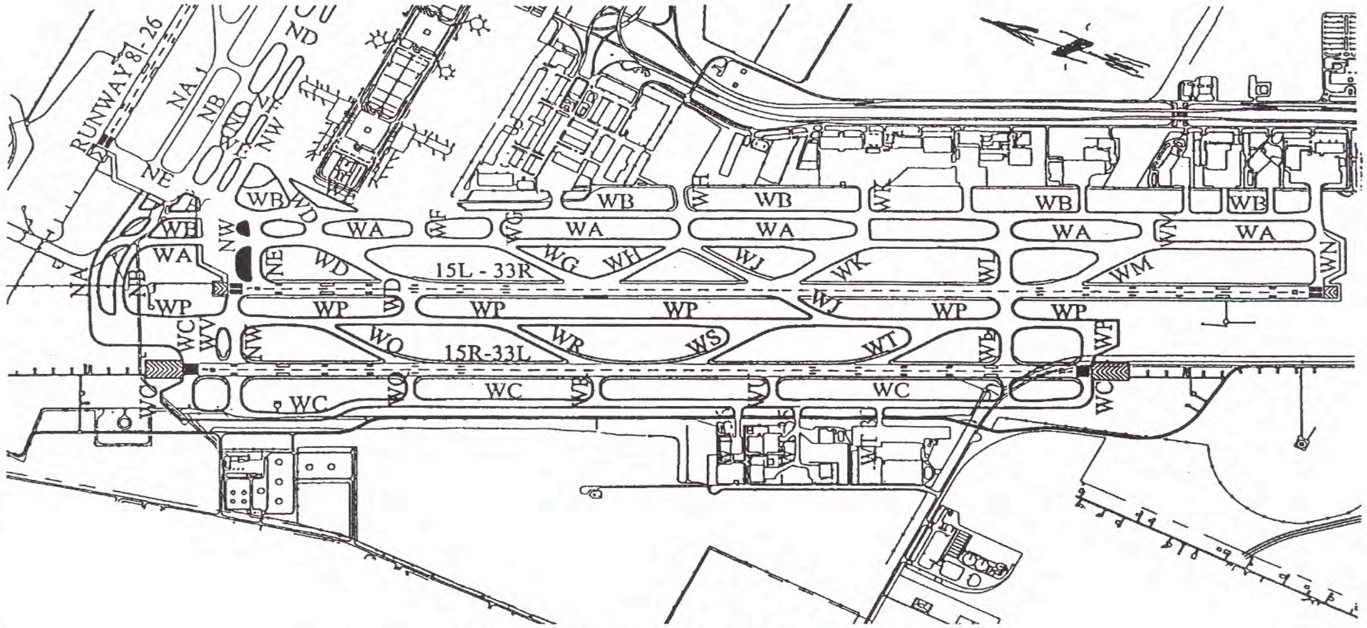

HOUSTON AIRPORT SYSTEMS
PROJECT 556 RUNWAY 15R - 33L EXTENSION AND WIDENING
GEORGE BUSH INTERCONTINENTAL AIRPORT / HOUSTON
PROPOSED WEST COMPLEX

Figure 1

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Godiwalla, Little, St.John
Tang, Oshiro

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Table 1 – Chemical Composition of Cement and Slag

Chemical Composition	Percentages for Portland Cement	Percentages for Class "C" Fly Ash	Percentages for Ground Granulated Blast Furnace Slag, Grade 120 (GGBFS)
CaO	65	31	42
SiO_2	20	35	38
AL_2O_3	4	17	8
Fe_2O_3	3	6	Trace
MgO	3	5	7
SO_3	3	3.5	--
S	--		1
Na_2O+K_2O	1	1.5	0.4
MnO	--	--	1

When GGBFS is coupled with cement, a synergistic combination is formed. Each product hydrates on its own, forming strength bearing calcium silicate hydrate (CSH). The excess silica from GGBFS and the excess calcium from cement react to form additional strength bearing CSH in the pore spaces of the concrete. This makes a stronger, denser matrix with decreased permeability. The chemical reactions are as follows:

$$\text{Cement} + H_2O = \text{CSH} + Ca(OH)_2$$
$$\text{GGBFS} + H_2O = \text{CSH} + SiO_2$$
$$SiO_2 + Ca(OH)_2 + H_2O = \text{CSH}$$

GGBFS also reduces the soluble alkalies in the mix. The result is concrete that is resistant to sulfate attack, chloride attack, and is less susceptible to alkali-aggregate reaction. GGBFS is more effective than Class "F" or Class "C" fly ash ashes or Portland cements in reducing alkali silica reactions and delayed ettringite formations. GGBFS, like fly ash, greatly reduces the heat of hydration, thereby mitigating shrinkage cracks and microcracking. Also, GGBFS like fly ash, increases the workability and facilitates the complete consumption of CAO in cement.

Concrete containing GGBF slag is found to respond very well under elevated temperature curing conditions. Conversely, strength gain is slower when cured at low temperatures. Of particular interest is the effect of GGBF slag when concrete is tested for flexural strength. The concrete with GGBF slag typically gives much greater flexural strength.

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predicted to be 119 years. Thus, the concrete can be assigned to the high strength/high performance category. Texas transportation Institute found to be the densest concrete they have investigated by petrographic analysis.

It is important to select the correct type of cement in the concrete.

Concrete Ingredients Portland Cement

Type of Cement	Description	Composition %			
		C_3S	C_2S	C_3A	C_4AF
I	General Purpose	48-50	24-26	5-13	7-9
II	Modified General Purpose	45-47	28-30	5-7	11-13
III	High Early Strength	55-57	14-16	11-13	7-9
IV	Low Heat	29-31	45-47	4-6	12-14
V	Sulfate Resistant	42-44	35-37	3-5	11-13

It is important to note that high amounts of C_3A like the ones in Type III cement cause ASR, delayed ettringite formation and thaumasite. It is important to use cements with $C_3A < 6$. In addition, it is important to use cements with Na alkali contents of $<0.6\%$.

Table 4 – Summary of Flexural Strength Results

Age of Specimen (days)	Flexural Strength (1) (psi)	Flexural Strength (2) (psi)
28	640	675
28	655	690
28	635	625
28	605	690
28	640	675
28	655	690
28	635	625
28	605	690
28	615	700
28	630	660
28	695	650
28	610	610
28	670	630
28	700	740
28	575	640
28	620	670
28	640	590
28	635	680

This is due to increased denseness of the paste and improved bond at the aggregate-paste interface. This is evident in the flexural strength results shown in Table 4.

With alkali silica reaction, a gel is formed that absorbs water and swells, exerting tremendous internal pressure that can lead to cracking of concrete. This cracking can provide pathways for potentially deleterious materials such as water, sulfates and chlorides to the interior of the concrete matrix, which in turn can lead to serious durability issues such as freeze thaw damage, sulfate attack or steel corrosion. Alkali silica reactivity weakens concrete so that day-in, day-out wear and tear becomes prematurely destructive. Alkali silica reaction has become to be recognized as a major contributor to concrete deterioration. The alkali silica reaction becomes more pronounced when numerous incompatible admixtures are used.

Resistance to alkali silica reaction is attributed to the following influences when GGBFS is used in concrete: (a) reduced permeability, (b) change of alkali-silica ratio, (c) dissolution and consumption of alkali species, (d) direct reduction of available alkali in the system, (e) reduction of calcium hydroxide needed to support the reaction.

Chemical Reactions in Fly Ash Concrete between Cement and Fly Ash

CaO

-Cementitious Materials

MgO

Al_2O_3
SiO_2 -Pozzolanic Materials
Fe_2O_3

$CaO+MgO+H_2O+Al_2O_3/SiO_2/Fe_2O_3$=Cementitious Paste+$Ca(OH)_2$

$Ca(OH)_2+Al_2O_3/SiO_2/Fe_2O_3$=Cementitious Paste

In concrete using only Portland cement, approximately 35% $Ca(OH)_2$ is formed, which lies dormant. By adding fly ash, the $Ca(OH)_2$ is utilized fully, because it reacts with the pozzolanic materials to form additional cementitious paste.

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which are not susceptible to alkali silica reaction. Extensive quality assurance and testing requirements were introduced in the concrete pavement specifications to eliminate this hazard, which is becoming more prevalent nowadays.

The concrete mix design was as follows:

Cement, Type I	270 lbs/C.Y.
Class "F" fly ash	135 lbs/C.Y.
Blast furnace slag, Grade 120	135 lbs/C.Y.
Total cementitious materials	540 lbs/C.Y.
Coarse aggregate (1:5" granite)	1,193 lbs/C.Y.
Fine aggregate (siliceous sand)	1,193 lbs/C.Y.
Water	209 lbs/C.Y.
Water – cementitious materials ratio	0.39
AEA	4.5 ozs/cwt
WRA	22.0 ozs/cwt

Here are the results of the petrographic analysis scanning election microscopic and other tests performed by the Texas Transportation Institute (Dr. Sarkar).

Copy of Figure 6.

Mortar Mixtures for ASTMC120 Test of ASR Resistance

The results plotted in Figure 2 confirm that the fine aggregate is reactive (expansion >0.20% at 14 days), and the coarse aggregate becomes marginally potentially reactive at 28 days. The mortar containing 25% fly ash and 25% slag either with coarse or fine aggregate is able to control the expansion to below 0.10% even at 28 days. This confirms that tertiary blend cementitious systems, when blended in the right proportions, can be very effective in controlling ASR.

Permeability

Figure 3 indicates that the concrete's permeability is extremely low.

Conclusions of the investigations performed by Texas Transportation Institute showed that the compressive strength ranged 6,730 psi to 9,790 psi at the age of 8 months. The electrical charge passed through the concrete was lower then 1,000 coulambs. Minearological analysis and microstructural did not reveal the presence of any deleterious materials. Its service life is

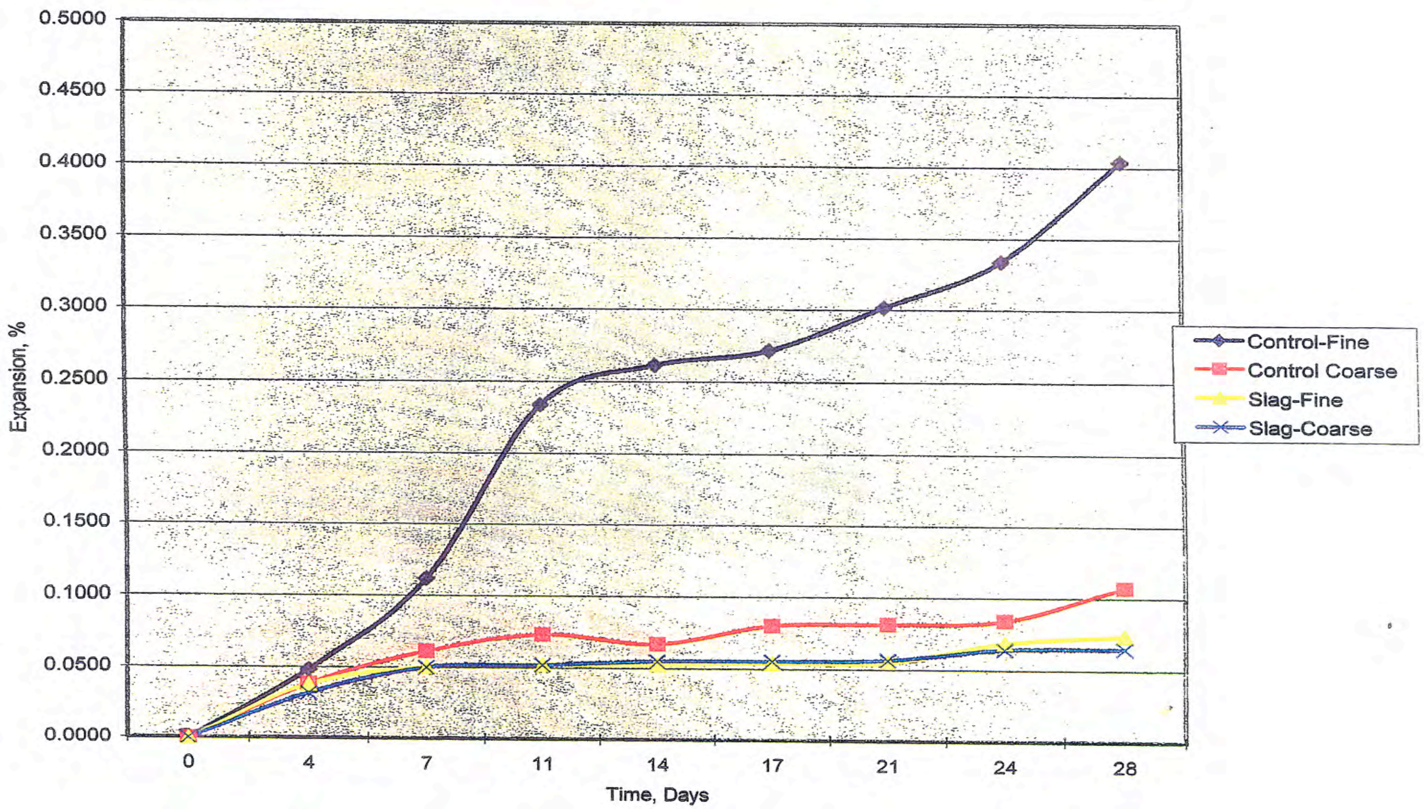
0.5000
0.4500
0.4000
0.3500
0.3000
0.2500
0.2000
0.1500
0.1000
0.0500
0.0000
Expansion, %
0
4
7
11
14
17
21
24
28
Time, Days
Control-Fine
Control Coarse
Slag-Fine
Slag-Coarse

Figure 6

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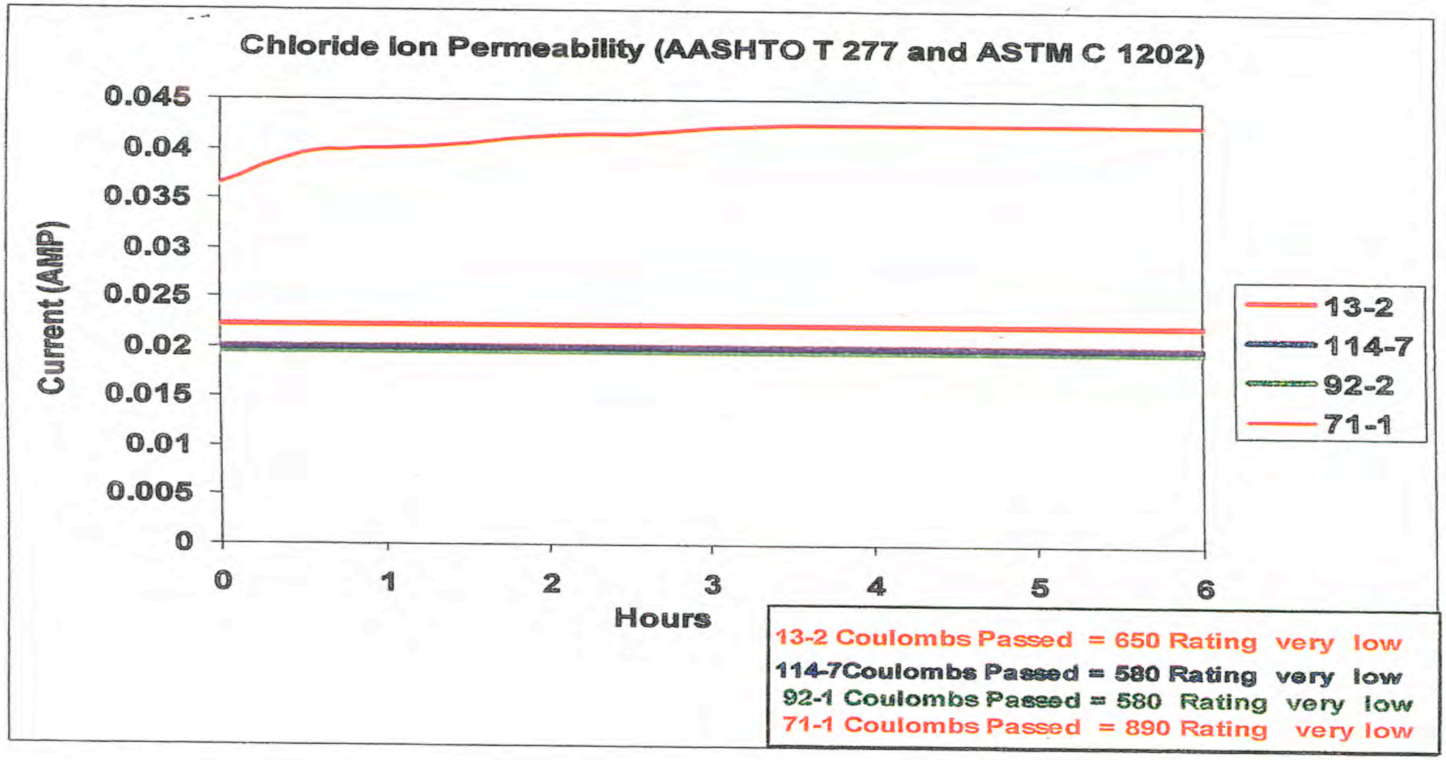

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RUNWAY 8L-26R WAS OPENED ON SCHEDULE ON OCTOBER 31, 2003

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WEST SAND PIT

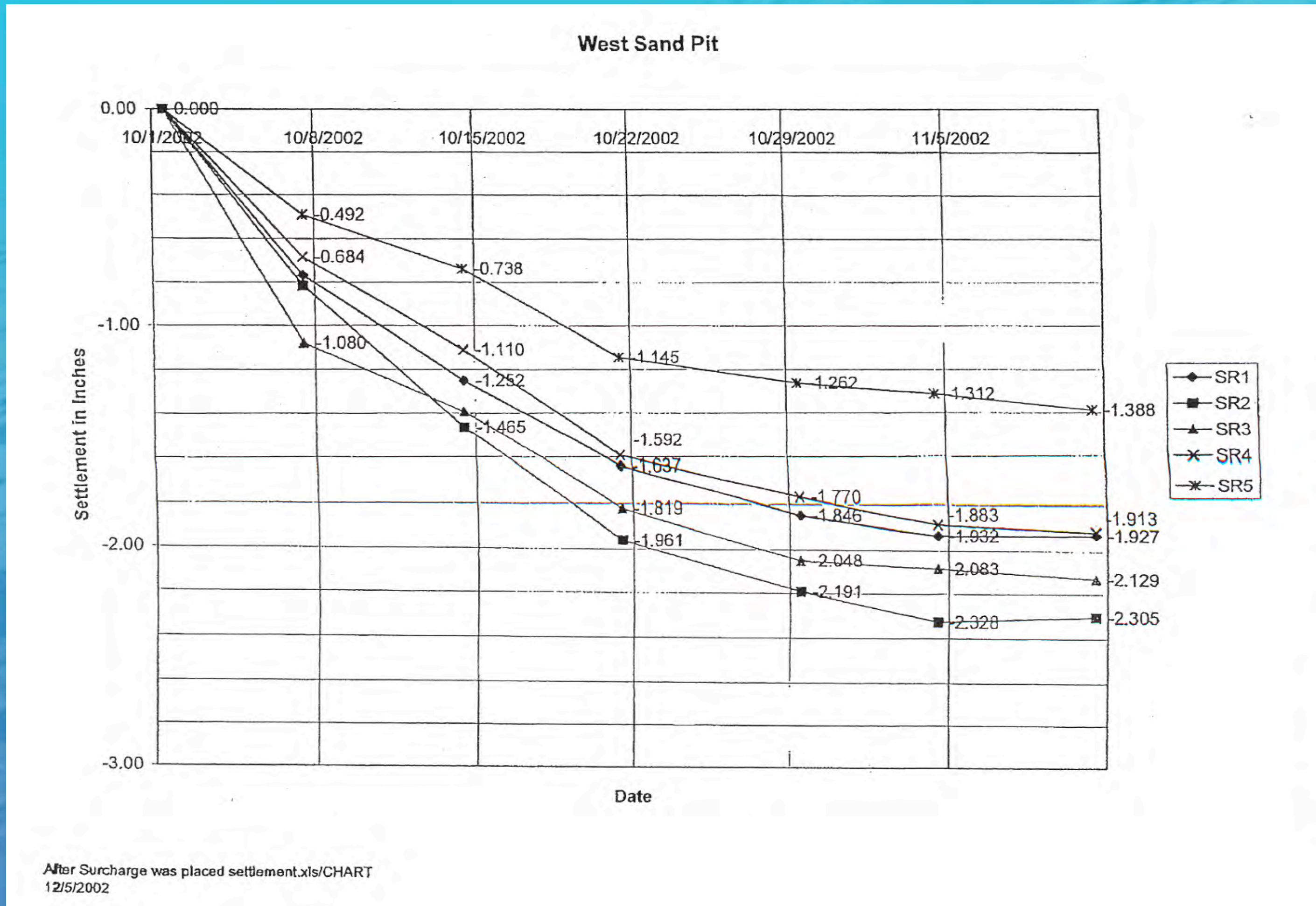

Figure 2: Settlement Monitoring on the West Sandpit.

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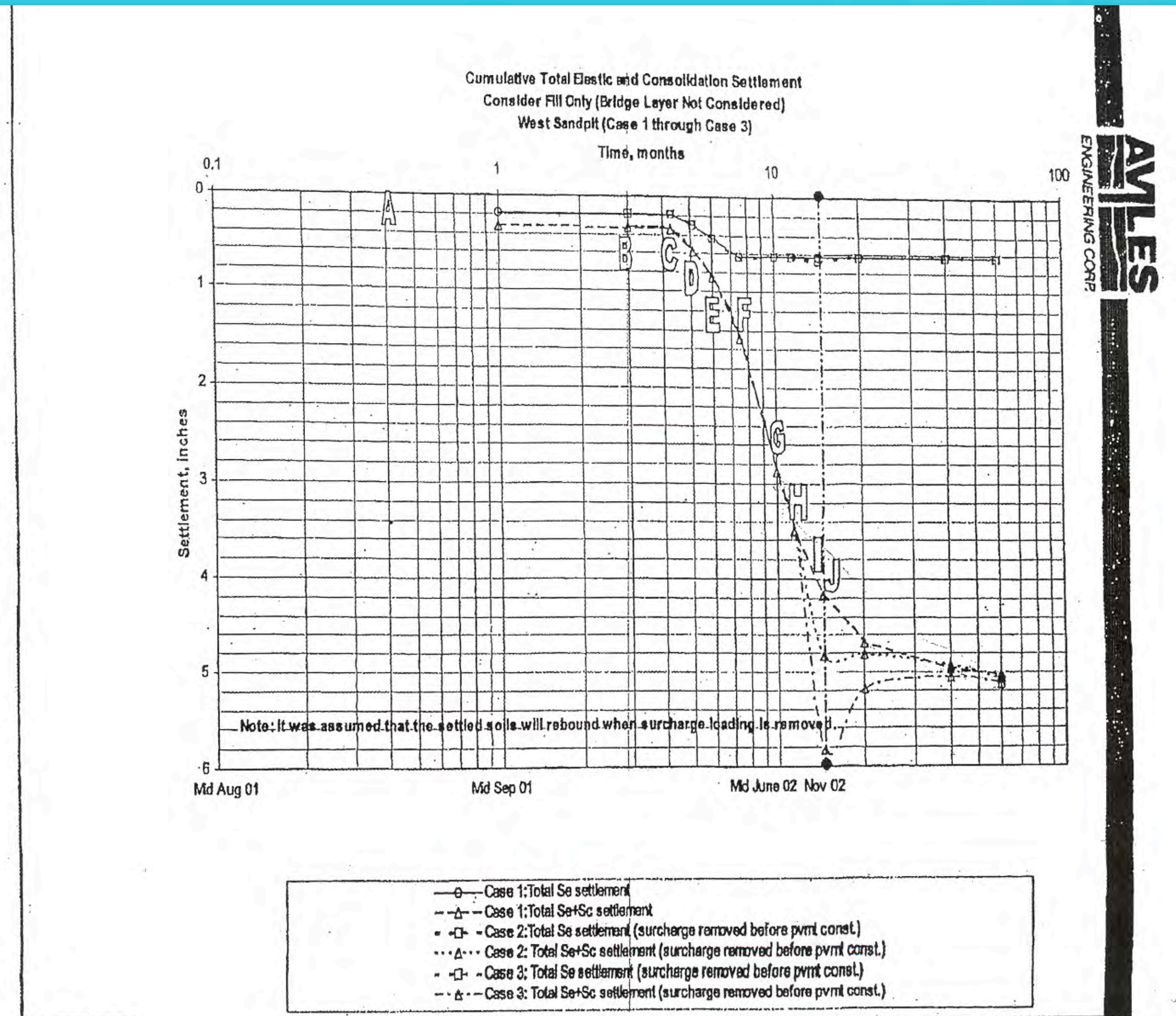

Figure 1: Settlement Prediction on the West Sandpit.

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AERIAL VIEW OF SURCHARGE ON OLD LANDFILL SITE

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RUNWAY AND TAXIWAY PAVEMENT CROSS-SECTION

The pavement cross-section selected for the Runway and Taxiways were as follows:

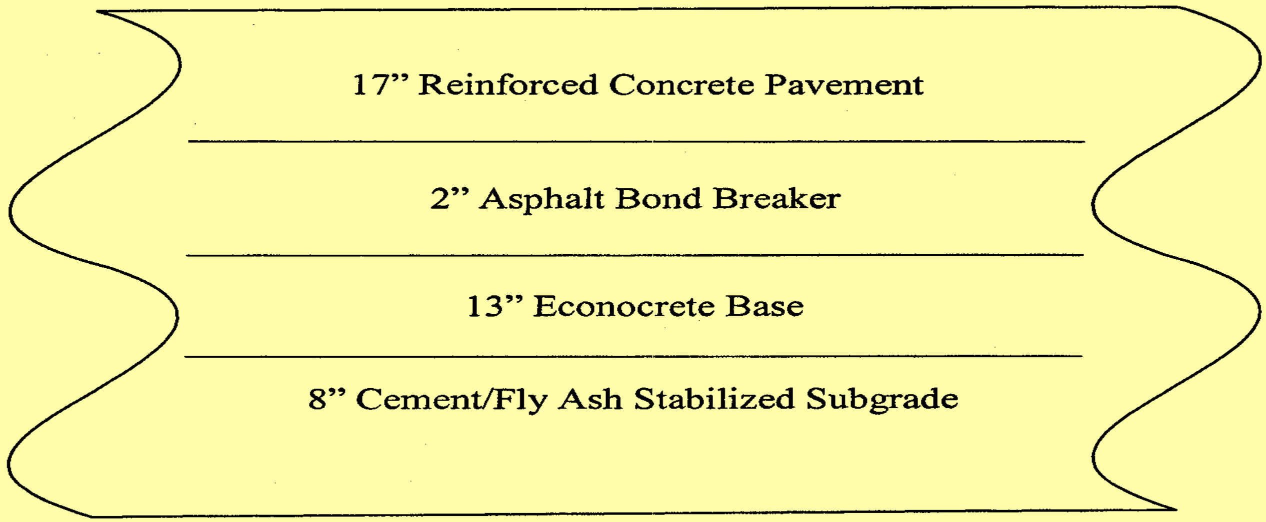

Figure 4: Runway and Taxiway Pavement Cross-Section

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AERIAL VIEW OF RUNWAY REHABILITATION

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INSITUFORM LINING

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PROJECT 491B – REHABILITATION OF RUNWAY 8R-26L

NDT Evaluation Updated 2003

IMPULSE STIFFNESS MODULUS

- **1998 ISM AVERAGED 4000 kips/inch**
- **2003 ISM AVERAGED 3000 kips/inch**

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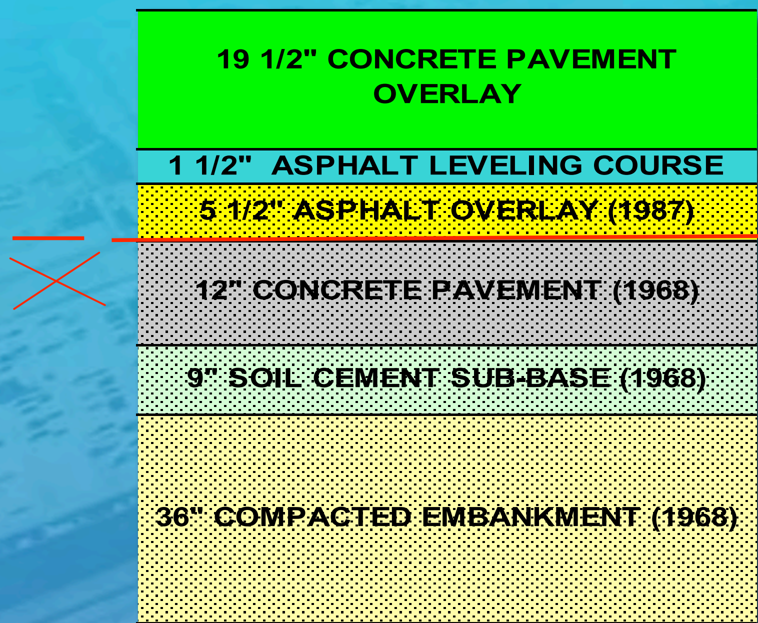
OVERLAY PAVEMENT CROSS SECTION



- NORMAL STRESS = 17.59 psi
- SHEAR STRESS = 7.9 psi
- PRINCIPAL STRESS = 25 psi
- DISPLACEMENT (DEFLECTIVE) = 0.065"
- NORMAL STRAIN = 0.0000057
- SHEAR STRAIN = 0.0000107
- PRINCIPAL STRAIN = 0.0001075

(ALL FOR X-AXIS)

STRESSES AND STRAINS ALONG X – X AXIS FOR BOEING 747 AIRCRAFT

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ADVANTAGES OF OVERLAY SOLUTIONS

- **REDUCED AFFECT ON AIRPORT OPERATIONS.**

TOTAL RECONSTRUCTION WOULD REQUIRE THE REMOVAL OF 1.25 MILLION TONS OF MATERIALS.

- **REDUCED CONSTRUCTION COSTS.**

ESTIMATED CONSTRUCTION COST OF FULL DEPTH REPLACEMENT TWICE AS MUCH AS REHABILITATED. $65 MILLION VERSUS $31 MILLION.

- **REDUCED CONSTRUCTION SCHEDULE.**

ESTIMATED CONSTRUCTION SCHEDULE WAS 12 MONTHS, VERSUS 7 MONTHS FOR REHABILITATION OPTION.

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BOTH TAXIWAY BRIDGES ARE DESIGNED TO ACCOMMODATE 1.6 MILLION POUND AIRCRAFT

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AERIAL VIEW OF TAXIWAY NP BRIDGE AND STORMWATER LIFT STATION

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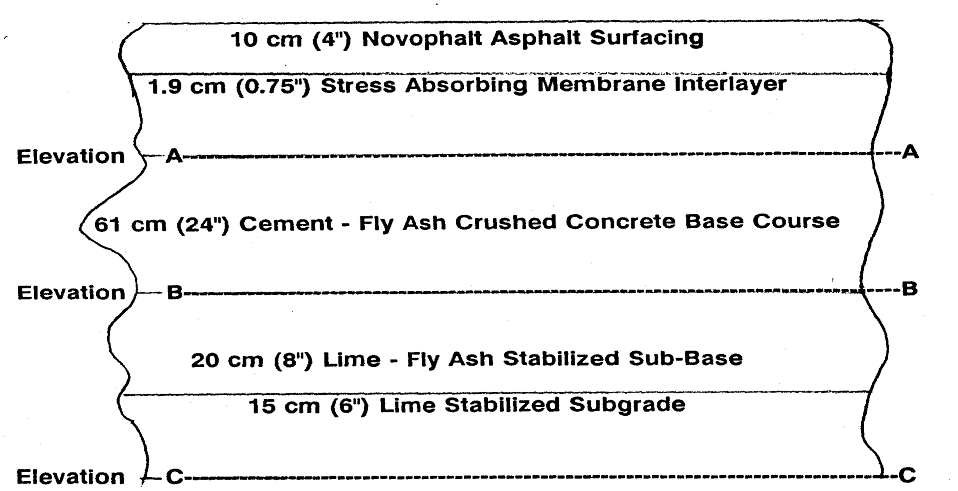
DISTRIBUTION OF STRESSES AND STRAINS IN THE VARIOUS LAYERS OF THE PAVEMENT ON TAXIWAYS

Figure 3. Distribution of Stresses and Strains in the Various Layers of the Pavement on Taxiways



	Elevation A-A	Elevation B-B	Elevation C-C
Normal Stress	1,033 kPa (150 psi)	1,047 kPa (152 psi)	6.13 kPa (0.89 psi)
Shear Stress	35.83 kPa (5.2 psi)	4.82 kPa (0.70 psi)	0.34 kPa (0.05 psi)
Principal Stress	1,033 kPa (150 psi)	1,040 kPa (151 psi)	6.13 kPa (0.89 psi)
Displacements	1.11 cm (0.44")	1.11 cm (0.44")	1.09 cm (0.43")
Principal Strain	0.00057	0.00031	0.00040
Normal Strain	0.00057	0.00031	0.00040

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QUESTIONS

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