

*Juan Santamaria International Airport
Rehabilitation Alternatives.*

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ISR & TAMS Consultants Inc.

September 1997

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**JUAN SANTAMARIA INTERNATIONAL AIRPORT
PAVEMENT REHABILITATION ALTERNATIVES**

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**JUAN SANTAMARIA INTERNATIONAL AIRPORT
PAVEMENT REHABILITATION ALTERNATIVES**

1. OBJECTIVE

Perform a current condition analysis for the airport run way, taxi way and gate areas pavements, in order to propose some pavement rehabilitation alternatives. The goal is to design a structurally adequate pavement, able to withstand the estimated future load until year 2010.

2. PAVEMENT VISUAL EVALUATION

2.1 Methodology

The pavement visual evaluation consisted of assigning a typical failure pattern to the whole pavement surface. Based upon the assigned failure patterns, it was possible to establish a group of homogeneous sections, by grouping together all sections under the same failure pattern.

By means of the visual evaluation it was possible to point out some aspects related to the pavement condition, which could be useful when defining appropriate rehabilitation alternatives.

2.2 Typical failure patterns

Failure patterns assigned to the pavement sections evaluated are listed and defined in Table No. 2.1.

Table N° 2.1: Typical pavement failure patterns.

PATTERN(1)	DESCRIPTION
F1	Healthy pavement, just some fissures covering less than 1 % of the total surface.
F2	Healthy pavement, just some fissures and/or pot holes on early formation stages, covering less than 5 % of the total surface. Beginning of the fatigue process.
F3	Alligator cracking, longitudinal cracking and/or pot holes on less than 10 % of the total surface.
F4	Alligator cracking, longitudinal cracking and/or pot holes on less than 20 % of the total surface. A structural rehabilitation by overlaying would require adequate preliminary repairs.
F5	Alligator cracking, longitudinal cracking and/or pot holes on less than 30 % of the total surface. Due to the advanced distress condition, an overlay might not be a rehabilitation procedure to consider.
F6	Advanced failure stage. Alligator cracking, longitudinal cracking and pot holes on more than 30 % of the total surface. Reconstruction receives strong consideration.

Note: (1) to characterize every pavement section, for each typical failure pattern, two severity levels will be considered. Thus, the higher severity level will be refer to as L2, and the lower severity level will be refer to as L1.

Appendix 4 consists of a series of example charts for every typical failure pattern.

Failure pattern F1 can be associated with a totally healthy pavement, F2 is related to a pavement in need of routine maintenance, and F3 corresponds to a pavement which needs some rehabilitation. The most advanced failure patterns (F4, F5 and F6) are related to pavements that have experienced a significant level of structural failure and require a major rehabilitation or reconstruction process.

2.3 Typical failure patterns assignment

As it was previously discussed, based on the visual evaluation, a failure pattern was assigned to every homogenous pavement section, as well as a severity level (L1 or L2).

The pavement separation into similar failure pattern groups is shown in Appendix II, including run way, taxi way, gate areas pavement and areas in between gates.

2.4 Additional information gathered by visual evaluation.

As the visual evaluation was performed, some important aspects were identified in some of the homogeneous pavement sections. This information is useful to evaluate the failure condition and to propose appropriate rehabilitation alternatives.

2.4.1 Run way pavement

LOCATION 1+000 a 1+150.

it is possible to appreciate a similar failure pattern on the whole run way pavement. It is common to find high severity longitudinal cracking, alligator cracking, settlements and fines pumping on the surface.

LOCATION 1+150 a 1+180.

Both lanes show a similar failure pattern, with cracks up to 19 mm wide. There is some fines pumping, and surface stripping.

LOCATION 1+180 a 1+450.

The left lane (Westbound) shows fatigue failure, and high severity longitudinal cracking. There is medium to high severity rutting, as well as pumping and high severity settlements.

The last 150 m in this section show a fatigue level somewhat lower than the rest of the section.

LOCATION 1+450 a 1+525.

Longitudinal cracking in this section left lane (Westbound) is not as severe as it is in the last section, neither is there surface fatigue in this lane.

LOCATION 1+800 a 1+910.

Both lanes have reached a high severity fatigue level.

LOCATION 2+075 a 2+500.

Lower severity rutting than the rest of the taxi way. Lower severity pumping, as well. Right lane (Westbound) has a somewhat higher failure severity level than the left lane.

LOCATION 2+500 a 2+900.

There has been a surface patching operation on both lanes (near the center line), although areas within 1.5 m away from center lane need patching. The patching mix seems to have a very fine graduation.

By the end of the section there are some curved cracks, which seem to be a consequence of the airplanes turning.

2.4.2 Gate areas

The places where airplanes stop at gates do not show a distress condition as severe as the taxi way. There is an overlay about two years old. There is some crack reflection. There are several longitudinal cracks in the areas where airplanes stop.

Areas in between gates, through where baggage and fuel pumping cars traffick, show an advanced failure condition, characterized by alligator cracking, pot holes and settlements.

In the area where cargo planes park and turn there are some surface construction defects, settlements and fuel spillage places. This area was rehabilitated a few years ago.

2.4.3 Run way

LOCATION 0+000 a 0+100 AND TURNING ZONE (BEGINNING OF THE RUN WAY)

Fatigue cracking, with no significant rutting. This indicates that the fatigue is superficial, expecting a good structural condition on the underlying layers. There are some pot holes already patched.

There are some big pot holes in the turning area, showing some surface stripping (ravelling) and settlements. Additionally, there is a localized asphalt bleeding problem.

LOCATION 0+100 a 0+400.

Longitudinal cracking, asphalt oxidation can be seen in the far lateral areas, stripping problems. The areas near the center line have been repaired (patching).

LOCATION 0+400 a 0+500.

Almost this entire section has been repaired by top surface milling and overlaying, which covers all pavement width, but the farthest 3m on each side.

LOCATION 0+550 a 0+800.

Some alligator cracking and low severity surface stripping, in some places.

LOCATION 0+950 a 1+150.

The pavement center area shows a lower severity failure level than the side areas.

LOCATION 1+150 a 1+280.

Higher severity level than almost the rest of the run way pavement. A core was extracted from the pavement, it remains open and full of water. From the core extraction it is possible to identify two asphalt concrete layers on top of the structure, each 5 cm thick.

LOCATION 1+280 a 1+500.

The cracked area is bigger than cracked area in last section. There is a big area covered with pot holes.

LOCATION 1+650 a 1+800.

Pavement center area shows a lower severity failure level than side areas.

LOCATION 2+610 a 2+710.

Advanced failure condition has been found in the surface layer, but, since there is no settlement or rutting, it is assumed that the failure condition is merely superficial.

LOCATION 2+710 a 2+785.

Pavement side areas were recently repaired and show no distress. Left lane (Westbound) has been repaired in a length of about 40 m, while right lane has been repaired in a length of about 120 m.

LOCATION 2+900 a 3+000.

There is some transverse cracking, surface stripping and some asphalt oxidation evidence.

3. EQUIVALENT ANNUAL DEPARTURES PROJECTION

Equivalent annual departures calculation is based on take off projections, done by TAMS Consultants Inc., taking year 2010 as the design horizon.

Total annual departures represent total load over the pavement. To measure frequency and magnitude of such load, individual airplane take off projections are used and converted to equivalent design airplane take offs, taking into account each airplane landing gear configuration and gross weight.

Equivalent annual take offs are calculated according to Federal Aviation Administration circular No. 150/5320-6D (Ref. 1). The standard criterion on airplane weight distribution (95 % over landing gear configuration) is followed. According to the established design method, only aircraft take offs are considered, while landing airplanes load is not included in the pavement thickness calculation, due to its lower fuel weight.

3.1 Year 2010 airplane departures forecast

Juan Santamaria International Airport departures forecast, by plane type, for year 2010, is shown in Table No. 3.1. This forecast was performed by Tams Consultants Inc.

Table N° 3.1: Year 2010 airplane departures forecast.

AIRPLANE TYPE	REAR LANDING GEAR CONFIGURATION	ANNUAL DEPARTURES	GROSS WEIGHT	
			(kg)	(lb)
320	dual	3545	77162	169756
727	dual	5081	95200	209439
737	dual	9311	68143	149914
757	dual tandem	3072	116244	255736
767	dual tandem	945	187393	412264
ARJ	dual	1182	46097	101413
M11	dual tandem + center	496	284597	626113
TOTAL		23632		

Source: TAMS Consultants Inc.

3.2 Design airplane selection

In order to decide which the design airplane is, it is required to perform an individual design for every airplane, selecting the airplane which determines the critical design (thickest layers).

For design purposes, tables from FAA circular No. 150/530-6D (Ref. 1) were used. Based on the information in Table No. 3.1, a design for every airplane was performed, with the layer thicknesses shown in Table No. 3.2.

It was considered an existing sub-grade with a CBR (California Bearing Ratio) equal to 5 %, as well as an existing granular sub-base with a CBR equal to 15 %. Such information was taken from The study on the development of an international airport in Costa Rica, by the Japan International Agency (Ref. 7).

Table N° 3.2: Design thicknesses for individual airplane types.

AIRPLANE	T sub-grade		T sub-base		H sub-base		H base		H surface	
	(cm)	(in)	(cm)	(in)	(cm)	(in)	(cm)	(in)	(cm)	(in)
320	96,5	38	48,3	19	48,3	19	38,1	15	10,2	4
727	109,2	43	53,3	21	55,9	22	43,2	17	10,2	4
737	96,5	38	48,3	19	48,3	19	38,1	15	10,2	4
757	86,4	34	38,1	15	48,3	19	27,9	11	10,2	4
767	96,5	38	45,7	18	50,8	20	35,6	14	10,2	4
ARJ	68,6	27	33,0	13	35,6	14	22,9	9	10,2	4
M11	116,8	46	55,9	22	61,0	24	45,7	18	10,2	4

Note: T sub-grade is the total pavement thickness; T sub-base is the required total thickness on top of the sub-base (base and asphaltic surface); H sub-base is the required sub-base thickness; H base is the required granular base thickness; H surface is the required asphaltic surface thickness.

There is no design chart for a dual tandem + center landing gear configuration (M11), therefore the dual tandem + center M11 take offs were converted to dual tandem 767 take offs, in order to use the 767 design chart, which is the heaviest airplane expected to arrive in the Juan Santamaria International Airport, apart from the M11. Consequently, 496 annual dual tandem + center M11 take offs represent 843 dual tandem take offs, with no gross weight correction yet. Furthermore, 843 dual tandem 626113 pound take offs are equivalent to 879 dual tandem 412264 pound take offs (same landing gear and gross weight as the 967 considered in the design analysis).

The critical design (thickest layers) is the one for the M11. Nevertheless, due to the following reasons:

- (1) Total M11 annual departures is 496 in year 2010. Total 727 annual departures is 5081 in year 2010.
- (2) Total M11 annual departures is 221 in year 2000. Total 727 annual departures is 3533 in year 2000.
- (3) 727 design thicknesses are quite similar to M11 ones.

B 727 is selected to be the design airplane, being necessary to include additional safety factors when considering the rehabilitation alternatives.

Once rehabilitated, the pavement is to have a 15 year design period, therefore, for all design purposes the annual total departures to consider will be the ones for year 2010 (tenth or eleventh in-service year), since it is near the end of the 15 year design period.

3.3 Design equivalent annual departures

By using the design aircraft (B-727), the design equivalent annual departures are calculated in Table No. 3.3, based on the departures forecast for year 2010.

Table N° 3.3: Design equivalent annual take offs.

Airplane	landing gear	annual take offs	gross weight (lb)	landing gear conversion factor (1)	landing gear adjusted annual departures	wheel load (lb)	design aircraft wheel load (lb)	equivalent annual departures (2)
320	dual	3545	169756	1.0	3545	40320	49740	1570
727	dual	5081	209439	1.0	5081	49740	49740	5081
737	dual	9311	149914	1.0	9311	35600	49740	2279
757	dual tandem	3072	255736	1.7	5223	30370	49740	804
767	dual tandem	945	412264	1.7	1607	48960	49740	1516
ARJ	dual	1182	101413	1.0	1182	24090	49740	137
M11	dual tandem + center	496	626113	1.7	844	49570	49740	834
TOTAL								10652

Source: TAMS Consultants Inc.

Notes:

(1) Landing gear conversion factor turns every landing gear configuration annual departures into the design airplane landing gear configuration (dual) annual departures total, for every airplane type.

(2) Equivalent annual departures are calculated from the following equation:

$$\log (R_2) = \log (R_1) * [W_1 / W_2]^{1/2}$$

R₁ = annual departures adjusted by landing gear.

R₂ = equivalent annual departures.

W₁ = wheel load.

W₂ = design airplane wheel load.

4. LABORATORY DATA ANALYSIS

It was possible to obtain information from the JAICA (Japan International Cooperation Agency, Ref. 7, 1992) and the OACI (Organización de Aviación Civil Internacional, Ref. 2, 1996).

It was not possible to gather information on previous rehabilitation works, ampliation works, or construction blue prints.

4.1 JAICA report

The laboratory data presented in this document is as follows.

4.1.1 SPT tests

In this test procedure, besides from finding the N value, a visual characterization for different sub-grade depths was performed. Also, natural moisture percentage was measured, as well as sub-grade gradation and Atterberg limits.

Not far away from the sub-grade top there is a clay type material, with medium to high plasticity. Generally, its highest liquid limit values range from 80 to 88, and its highest plasticity index values range from 30 to 35.

4.1.2 Pavement coring

This report shows the typical pavement section in 12 core extractions along the whole run way field. Table N° 4.1 shows location and results gathered.

Table N° 4.1: Pavement typical sections.

Core No	Location	Thickness (cm)			Total thickness (cm)
		surface (1)	cement treated base (2)	sub-base (3)	
1	(*)	11		52	63
2	(*)	10		55	65
3	(*)	10		68	78
4	1+ 200 N	14	26	85	125
5	1+ 900 N	13	20	77	110
6	2+ 800 N	10	25	55	90
7	2+ 900 S	30	20	90	140
8	2+ 400 S	60		70	130
9	1+ 800 S	36		54	90
10	1+ 300 S	34		66	100
11	0+ 700 S	35		75	110
12	0+ 200 S	23	24	53	100

Notes:

- (1) Asphaltic concrete surface layer.
- (2) Cement treated base
- (3) Granular base and sub-base (no distinction made).
- (*) Aprons.

From this table, it is possible to establish the following variation among thicknesses along the run way:

- Asphaltic surface: 10 to 60 cm.
- Cement treated base (CTB): 20 to 26 cm.
- Granular layers: 52 to 90 cm (*).

(*) In order to rehabilitate the pavement structure, the pavement was divided into homogeneous sections, assigning a typical section to every one of them, as follows next.

Section N° 1 (West, 400 m):

Asphaltic surface: 26 cm.

Granular base: 23 cm.

Sub-base: 90 cm.

Section N° 2 (Center, 2012 m):

Asphaltic surface: 42 cm.

Granular base: 22 cm.

Sub-base: 32 cm.

Section N° 3 (East, 600 m):

Asphaltic surface: 25 cm.

Granular base: 31 cm.

Sub-base: 63 cm.

Additionally, there are 17 Marshall parameters results (each of them as a three sample average) for the asphaltic surface mix. The next parameters were evaluated:

- Bulk specific gravity.
- Stability.
- Flow.

4.1.3 Pavement visual evaluation

The report has a pavement condition visual evaluation, focusing on several research areas. The information is summarized in schematic maps, which emphasize these aspects:

- Location and size of settlements and pot holes in the pavement.
- Cracking pattern (longitudinal, transverse or alligator).
- Corrugations.

4.1.4 Sub-grade load bearing ability

- The following values were gathered for the run way.

Sample	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
CBR	6	2.3	4	12	12	11	10	10	8	7	7	7	7	7	6	6	5

CBR (average) = 6.8 %

CBR (design) = $6.8 - (12 - 2.3) / 5.382 = 5\%$

- Taxi way and gate pavement areas:

Sample	1	2	3	4	5	6	7
CBR	7	5	4	3.5	3	3	2.5

CBR (average) = 4.0 %

CBR (design) = $4 - (7 - 2.5) / 4.059 = 3\%$

In this report, the following pavement was suggested, for the 1991 - 2000 period.

- Run way:

Total thickness: 122 cm.

Asphaltic surface: 13 cm.

Granular base: 36 cm.

Sub-base: 73 cm.

- Taxi way:

It is advised to substitute the top 60 cm sub-grade material with a 10 % CBR material, in order to achieve an effective 5 % CBR for the rehabilitated sub-grade.

Following the sub-grade material substitution, since the CBR rises up to 5 % (from an initial 3 %), it is recommended to build a pavement with the same thicknesses as the recommended for the run way.

4.2 OACI report

This report points out the pavement lack of structural adequacy and refers to the considerable distress levels, the infiltration problem and an inadequate drainage.

This report is based on 26 core extractions throughout the Airport pavement. The report information is summarized as follows.

- **Run way:**

Core N ^o	Thicknesses (cm)			Total (cm)
	Asphaltic surface	Base	Sub-base	
1	20	28	87	135
2	20	26	89	135
3	40	25	25	90
4	42	30	23	95
5	60	20	20	100
6	60	20	25	105
7	42	20	33	95
8	46	20	29	95
9	46	25	24	95
10	33	25	22	80
11	29	25	31	85
12	25	30	35	90
13	30	25	30	85
14	43	20	32	95
15	23	30	38	91
16	25	40	39	104
17	15	30	90	135
18	25	20	60	105

- **Taxi way:**

Core N ^o	Thicknesses (cm)			Total (cm)
	Asphaltic surface	Base	Sub-base	
18A	14	30	37	81
19	12	26	49	87
20	14	40	41	95
21	15	40	38	93
22	11	35	57	103

- **Gate areas:**

Core N ^o	Thicknesses (cm)			Total (cm)
	Asphaltic surface	Base	Sub-base	
23	14	26	75	115
24	13	25	41	79
25	9	30	36	75

- **Pavement design:**

In order to design the run way and taxi way pavement, this report considers the airplane departures forecast until year 2010, and estimates a CBR of 5 % for the run way sub-grade material, and a CBR of 3 % for the taxi way sub-grade material. Consequently, the following structural scheme is proposed.

- **Run way:**

Asphaltic surface: 13 cm.

Granular base: 36 cm.

Sub-base: 83 cm.

Total thickness: 132 cm.

- **Taxi way and gates area:**

Asphaltic surface: 13 cm.

Granular base: 36 cm.

Sub-base: 91 cm.

Total thickness: 140 cm.

It is important to consider that the proposed thicknesses do not consider any structural adequacy reduction due to current in-service distress.

4.3 RESULTS SUMMARY

From the laboratory information, the following conclusions were stated.

- There is a wide range of variation among the measured thicknesses, specially in the run way, which makes it hard to estimate the pavement structural configuration. It is required to conduct a bigger number of core extractions and find out the exact location cores were extracted from, in order to be certain of the current pavement typical sections.

- Further research on the existing layers materials quality is necessary, in order to correct the current thicknesses on the basis of their distress level, failure or pavement conditions (site density, cracked cement treated bases, cracked or aged asphaltic surface, granular base material polluted with clay, etc.).

- There is no information regarding the level bellow which underground water is located. This condition has to be associated to the season coring takes place (rainy or dry season).

5. PAVEMENT DESIGN

This section involves the actual pavement design. As a result of the design analysis, several rehabilitation alternatives will be proposed, assuming a new pavement design. In the next section, the design about to be developed will be adapted to the current pavement condition, in order to establish several possible rehabilitation procedures.

Taking into account all available information on the sub-grade condition, a distinction is made between the taxi way sub-grade load bearing ability and the run way sub-grade load bearing ability. Therefore, the pavement structure layers thicknesses will be determined based upon the following information:

- (1) Taxi way sub-grade CBR of 3%.
- (2) Run way sub-grade CBR of 5 %.
- (3) Taxi way sub-base CBR of 18 %, properly compacted.
- (4) Run way sub-base CBR of 15 %, properly compacted.
- (5) Equivalent annual departures: 10652.
- (5) Design airplane: B-727, with a gross weight of 95200 kg (209439 lb) and a dual landing gear configuration.
- (6) In addition, the taxi way pavement is also designed considering an electro-chemical injection in the clay sub-grade, assuming a 10 % CBR will be achieved. Also, the possibility of a sub-base cement injection will be assessed.
- (7) Finally, two alternative pavement designs are proposed for a new Airport pavement (such as a new run way or a new taxi way), one for a flexible pavement and one for a rigid pavement. In such cases the sub-grade bearing ability is supposed to be 5 % (CBR).

The structural requirements for a flexible pavement will be determined for both the taxi way and the run way, as well as the structural requirements for a rigid pavement for the taxi way.

The nominal thicknesses obtained from this new pavement analysis have to be modified to account for the current distress level on the existing pavement, which have an effect on the layer resilient moduli and/or the effective layer thicknesses (see Section 6).

It is required to point out the convenience of verifying the structural design which is proposed in this report, performing a fatigue analysis on the existing pavement structure. Therefore, to reach such analysis level, it is necessary to have further field and laboratory information, in order to establish the current resilient moduli, as well as a more accurate knowledge on the pavement typical layer thicknesses, for a series of homogeneous sections defined accordingly to their layer thicknesses and materials (for example there are some areas with a cement treated base, whereas there are others with only a granular base). Additionally, the airplanes tire pressure and the gear configuration are important elements to incorporate into such analysis.

5.1 Taxi way pavement design

It is possible the gate areas pavement sub-grade has a higher load bearing ability than the taxi way one. Therefore, even though in both cases the pavement structure is similar, the difference in sub-grade load bearing ability would determine a minor structural reinforcement for the gate areas. Nevertheless, in a conservative point of view, and due not to have any information on the gates area sub-grade condition, it is assumed the gate areas have a similar sub-grade condition to the taxi way pavement; consequently, their rehabilitation alternatives will be supposed to be the same. In order to determine a more accurate rehabilitation alternative for the gate areas, it is necessary to perform the corresponding laboratory tests on the gate areas sub-grade.

5.1.1 Taxi way flexible pavement design

According to Figure No. 3-3 (Appendix 3, corresponding to a dual tandem landing gear), on circular No. 150/5320-6D (Ref. 1), using a sub-grade CBR of 3 %, a gross weight of 95200 kg (209439 lb), and 10652 equivalent annual departures, the required total pavement thickness is 147 cm (58 in).

Considering a 18 % CBR sub-base and the mentioned figure, the required thickness for the granular base and asphaltic surface together is 48 cm (19 in).

According to the design diagram (Figure No. 3-3), the minimum asphaltic surface thickness is 10 cm (4 in). Nevertheless, this thickness has to be adjusted by distress condition and design safety considerations. Consequently, a 15 cm thick asphaltic surface is proposed.

By difference, the sub-base thickness must be 99 cm (147 cm - 48 cm) and the base thickness has got to be 33 cm (48 cm - 15 cm).

In conclusion, the proposed design is:

- Asphaltic surface: 15 cm.
- Granular base: 33 cm.
- Sub-base: 99 cm.

5.1.2 Taxi way and gate areas rigid pavement design

A 3 % CBR sub-grade material determines a reaction modulus of 2.8 kg/cm^3 (100 pci), accordingly to AASHTO standard rigid pavement design procedure. Considering a granular sub-base not thinner than 12 cm (4.7 in), the reaction modulus increases to 3.7 kg/cm^3 (135 pci). A 24 cm (9.5 in) cement treated base placed on top of the sub-base determines a reaction modulus of 9.7 kg/cm^3 (350 pci).

Considering a Portland cement concrete modulus of rupture of 45 kg/cm^2 (640 psi), for the slab; a modulus of reaction of 9.7 kg/cm^3 (350 pci), for the underlying layers; 10652 equivalent annual departures and a design airplane gross weight of 95200 kg (209439 lb); by means of Figure No. 3-18 of FAA circular No. 150/5320-6D, it is determined that the required slab thickness is 43 cm (16.9 in).

In addition, it is highly recommended to place an 10 cm (2.5 in) asphaltic base, in order to prevent the slab from cracking in the interface with the cement treated base. Therefore, the cement treated base thickness may be reduced up to 4 cm, given the structural ability of the asphaltic base.

In conclusion, the proposed design is as follows:

- Portland cement concrete slab: 43 cm.
- Asphaltic base: 10 cm.
- Cement treated base: 20 cm.
- Sub-base: 12 cm.

5.1.3 Taxi way flexible pavement design. Sub-grade load bearing ability increased by a sub-grade electro-chemical injection

From Figure No. 3-3 in FAA circular No. 150/5320-6D (Ref. 1), assuming a 10 % CBR sub-grade (result of an electro-chemical injection), a total pavement thickness of 76 cm (29.5 in) is determined.

Based on a 18 % CBR sub-base, according to the mentioned figure, it is required a 51 cm (20 in) total thickness for granular base and asphaltic surface together.

Figure No. 3-3 establishes a minimum asphaltic surface of 10 cm (4 in). Nevertheless, due to design safety considerations and maintenance interference reduction, it is strongly recommended to build a 15 cm thick asphaltic surface instead.

By difference between the base and asphaltic surface layers total thickness, and asphaltic surface thickness itself, the resulting granular base thickness is 36 cm (51 - 15 cm).

By difference between the total pavement thickness, and the base and asphaltic surface layers total thickness, the resulting sub-base thickness is 25 cm (76 - 51 cm).

In conclusion, the proposed design is as follows:

- Asphaltic surface: 15 cm.
- Granular base: 36 cm.
- Sub-base: 25 cm.

5.2 Run way flexible pavement design

According to Figure No. 3-3, from FAA circular No. 150/5320-6D (Ref. 1), for a 5 % CBR subgrade, design airplane gross weight of 95200 kg (209439 lb) and 10652 equivalent annual departures, the required total pavement thickness is 117 cm (45 in).

Considering a 15 % CBR sub-base (Ref. 7), and following the mentioned design chart (Figure No. 3-3), the required thickness for both base and asphaltic surface together is 57 cm (22.5 in).

Once again, the design chart states a minimum asphaltic surface thickness of 10 cm (4 in). Nevertheless, due to the same safety considerations and future rehabilitation time savings, it is recommended to place a 15 cm (6 in) thick asphaltic surface instead.

By difference between the base and asphaltic surface layers total thickness, and asphaltic surface thickness itself, the resulting granular base thickness is 42 cm (57 - 15 cm).

By difference between the total pavement thickness, and the base and asphaltic surface layers total thickness, the resulting sub-base thickness is 60 cm (117 - 57 cm).

In conclusion, the following design is proposed:

- Asphaltic surface: 15 cm.
- Granular base: 42 cm.
- Sub-base: 60 cm.

5.3 Structural requirements

According to the developed designs, the 15 year period design requirements, based on the forecasted load level, are as follows.

(1) The taxi way flexible pavement structure must consist of the equivalent of a new condition 99 cm thick granular sub-base (18 % CBR), a new condition 33 cm thick granular base and a 15 cm thick new condition asphaltic surface. Based on a 3 % CBR sub-grade (current sub-grade condition).

(2) The taxi way rigid pavement structure must consist of the equivalent of a new condition 12 cm thick granular sub-base (as a minimum requirement), a new condition 20 cm thick cement treated base, a new condition 10 cm asphaltic base, and a new condition 43 cm Portland cement concrete slab. Based on a 3 % CBR sub-grade (current sub-grade condition).

(3) Should a sub-grade injection be performed, in order to increase the taxi way sub-grade CBR to 10 %, the structural requirements are decreased to a new condition 25 cm thick granular sub-base (18 % CBR), a new condition 36 cm thick granular base, and a new condition 15 cm thick asphaltic surface.

(4) The run way pavement structure must consist of the equivalent of a new condition 60 cm thick granular sub-base (15 % CBR), a new condition 42 cm thick granular base, and a new condition 15 cm thick asphaltic surface. Based on a sub-grade CBR of 5 % (current pavement sub-grade condition).

These estimated thicknesses correspond to a healthy structure, with no failure whatsoever, with a 15 year design period under the forecasted load level. The actual rehabilitation alternatives to propose are based on an existing pavement actual distress level; consequently, the rehabilitation has to improve such structural adequacy in a way that the resulting pavement has an equivalent structure to the ones corresponding to an all new condition pavement (Section 5).

6. REHABILITATION ALTERNATIVES

Based upon the proposed structural designs in Section 5, this section shows the actual rehabilitation alternatives, in order to improve the current pavement structure. This section will define all rehabilitation alternatives typical cross sections.

6.1 Run way rehabilitation

6.1.1 Structural equivalency

Given the wide variation among thicknesses detected through the coring extraction, the rehabilitation alternatives will be proposed based on a typical cross section. Nevertheless, should further core extractions be performed, the Airport pavement may be divided into more accurate typical sections, according to the layer thicknesses and their material properties (such as granular base or cement treated base). In that way, the rehabilitation alternatives become more accurate, and therefore, less conservative.

Besides this thickness variability throughout the pavement length, it has to be considered that the existing pavement structural adequacy depends on the pavement layers quality and distress condition. This situation becomes more important in these cases:

- Aged or cracked asphaltic concrete (fatigued).
- Granular layers polluted with clay (fines pumping).
- Cracked cement treated bases.
- Low quality granular layers, due to inadequate gradation, round aggregate particles (low angularity), soundness, shape, site compaction, etc.

The pavement thicknesses range as follows (Ref. 7):

- Asphaltic surface: from 20 to 60 cm.
- Cement treated base: from 20 to 40 cm.
- Granular layers: from 20 to 90 cm.
- Pavement total thickness: from 80 to 135 cm.

To structurally readequate this pavement, the following aspects are to be considered:

- Required new pavement thickness: 117 cm.
- Required new condition layer thicknesses:

Asphaltic surface: 15 cm.

Asphaltic base: 42 cm.

Sub-base: 60 cm.

- Existing pavement thicknesses (typical cross section, percentile 70):

Asphaltic surface: 25 cm.

Granular base: 25 cm (*).

Sub-base: 25 cm.

(*). Supposedly the 20 cm thick layers correspond to a cement treated base, whereas thicker layers correspond to a granular base. The equivalency factor to convert a cement treated base thickness into a granular base thickness is 1.25.

- Existing pavement thicknesses adjusted by fatigue (estimated values):

Asphaltic surface: 18 cm.

Granular base: 21 cm.

Sub-base: 23 cm.

Note: in order to improve the correction factors precision, due to every layer distress level, it is necessary further field and laboratory research.

Thickness structural equivalency factors:

- a) Comparisson basis: P-154 sub-base (FAA, circular No : 150/5320-6D, Ref 1).

P-154 sub-base: 1.0

P-208 granular base: 1.25

P-209 granular base: 1.55

- b) Comparisson basis: P-209 granular base (FAA, circular No : 150/5320-6D, Ref. 1).

P-209 granular base: 1.0

P-304 cement treated base: 1.45

P-401 asphaltic concrete: 1.55

6.1.2 Proposed rehabilitation procedure:

- Recycle asphaltic surface top 10 cm.
- Place a 10 cm thick asphaltic base.
- Place a 12 cm thick asphaltic concrete overlay (surface layer).

As soon as the homogeneous sections definition is improved, based on further site and laboratory research, these thicknesses can be adapted to every particular section, depending on every particular cross section.

6.2 Taxi way and gates areas rehabilitation alternatives:

6.2.1 Flexible pavement reconstruction alternative

6.2.1.1 Structural equivalency

The existing thicknesses range as follows:

- Asphaltic surface: from 11 to 5 cm.
- Base layer: from 26 to 40 cm.

- Sub-base: from 37 to 57 cm.

Since there is just a few coring extractions, it is not possible to associate the typical pavement layer thicknesses to any confidence level (percentile), thus, the following are the chosen typical thicknesses:

- Asphaltic surface: 12 cm.
- Base: 28 cm (*).
- Sub-base: 40 cm.

(*) From the coring laboratory results, it is possible to establish that this material is a cracked cement treated base.

- Design new condition total thickness: 147 cm

- Design new condition layer thicknesses:

- Asphaltic surface: 15 cm.
- Granular base: 33 cm.
- Sub-base: 99 cm.

- Existing pavement thickness adjusted by fatigue:

- Asphaltic surface: due to its distress level it is advised to replace or recycle this layer.
- Base layer: due to its distress level it is advised to replace or stabilize this layer.
- Sub-base: 32 cm.

6.2.1.2 Taxi way structural rehabilitation procedure:

To restore this pavement structural ability, it is required to reconstruct the facility as follows.

- Remove all existing asphaltic surface material. Recycling may be an alternative.

- Remove part of the cracked cement treated base, adding new aggregates and stabilizing both new and reclaimed materials together, to build a 40 cm cement treated base.

- Place a 13 cm thick new asphaltic base.
- Place a 13 cm thick new asphaltic surface.

Therefore, the current pavement top rises about 26 cm, which is a considerable increase from current top level.

6.2.1.3 Gate areas pavement rehabilitation:

It is suggested to apply the same rehabilitation procedure recommended for the taxi way pavement, unless further laboratory and site research indicate otherwise, except that the current pavement should be removed until a depth of 60 cm. Therefore, the pavement surface level rises only about 6 cm. This difference from the taxi way rehabilitation procedure is due to the nearby building, therefore it is not practical to increase the existing pavement surface level very much.

6.2.1.3.1 Exterior gate areas pavement rehabilitation:

Based on the gate areas sub-grade load bearing ability being supposed to be similar to the taxi way one, together with the similar current pavement cross section between the gate areas and the taxi way, it is suggested to rehabilitate the pavement section airplanes pass by right before entering the gate areas, in the same way the taxi way has been suggested to be.

Regarding the areas between gates, where airplanes do not pass by, cheaper solutions are proposed next.

6.2.1.3.2 Area between gates pavement:

This area corresponds to the pavement section where no airplane trafficks, and usually only forklifts and service vehicles pass by.

Two rehabilitation alternatives are to be consider:

Despite there is a lack of laboratory information on this area, according to the visual evaluation it is practical to consider a less expensive rehabilitation alternative, which has the following goals: crack sealing, aged asphalt covering, slow down crack reflexion problems and slightly improve the pavement structural adequacy. To do so, it is required to:

- Apply an asphaltic crack seal.
- Build a membrane-type asphaltic layer (2.5 cm thick).
- Place a 7 cm overlay.

This alternative feasibility depends on the existing pavement structural condition. It is suggested to perform an extensive deflexion analysis, as well as some core extractions.

To perform the membrane-type asphaltic mix design, adding an aditive, such as a polimer, has to be considered.

As a second alternative, it is proposed to reconstruct the existing pavement, recycling current site materials. Given an eventual pavement high severity failure level, this would be the best long term

alternative. Nevertheless, such high severity failure level may be verified only by performing further laboratory research.

The proposed reconstruction alternative is as follows:

- Remove current asphaltic surface and base material up to a 37 cm depth below pavement surface top.
- Recompact remaining existing 20 cm top surface material.
- Place a 29 cm thick cement treated base. Existing material may be recycled and stabilized.
- Place a 7.5 cm thick asphaltic base.
- Place a 7.5 cm thick asphaltic surface.

6.2.2 Taxi way and gate areas rigid pavement alternative

In order to rehabilitate the pavement in these areas, by placing a Portland cement concrete slab, it is recommended to apply the following rehabilitation alternatives.

- **Taxi way**

- Remove existing pavement top 65 cm.
- Recompact the existing sub-base top 14 cm.
- Place a 20 cm thick cement treated base.
- Place a 10 cm thick asphaltic base.
- Build a 43 cm thick Portland cement concrete slab.

As a consequence of this rehabilitation alternative the pavement top rises 8 cm up from current top level.

6.2.3 Taxi way and gate areas injection as rehabilitation alternatives

6.2.3.1 Sub-grade injection

In this case, the following is suggested.

- Perform an electro-chemical additive sub-grade injection, until the sub-grade CBR rises up to not less than 10 %.
- Place a 15 cm thick asphaltic concrete overlay on top of the rehabilitated pavement. In this rehabilitation alternative, the resulting pavement top is about 1 to 4 cm over the existing one.

6.2.3.2 Sub-base injection

In this option it is considered to perform a cement injection to the existing sub-base layer.

Based on a sub-base injection, until its resilient modulus is higher than 200000 kg/cm^2 (14000 psi), for a 40 cm thickness, the following rehabilitation alternative can be considered.

- Remove existing asphaltic surface and cement treated base. Recycling may be considered.
- Inject existing sub-base in a 40 cm thickness.
- Build a 40 cm thick cement treated base, stabilizing the removed cement treated base material.
- Place a 15 cm thick asphaltic surface.

Therefore, the pavement top rises about 1 to 4 cm, after performing this rehabilitation alternative.

6.2.3.3 Sub-base and sub-grade injection

Assuming the sub-grade CBR rises up to 10 %, and the sub-base is injected as stated on Section 6.2.3.2., the following is the proposed rehabilitation alternative.

- Remove existing asphaltic surface.
- Sub-grade injection.
- Sub-base injection for a 40 cm thickness.
- Crush and recompact existing cement treated base for a 27 cm thickness.
- Place a 15 cm thick asphaltic surface.

This alternative can be modified by considering the current cracked cement treated base stabilization, as well as asphaltic surface recycling, placing it in a 15 cm thickness. The pavement top rises up about 2 cm.

6.3 Rehabilitation alternatives summary

This section shows all proposed rehabilitation alternatives in a schematic way. As well, a new flexible pavement alternative and a new rigid pavement alternative are included. Appendix I presents information on each alternative estimated cost.

6.3.1 Run way rehabilitation alternatives

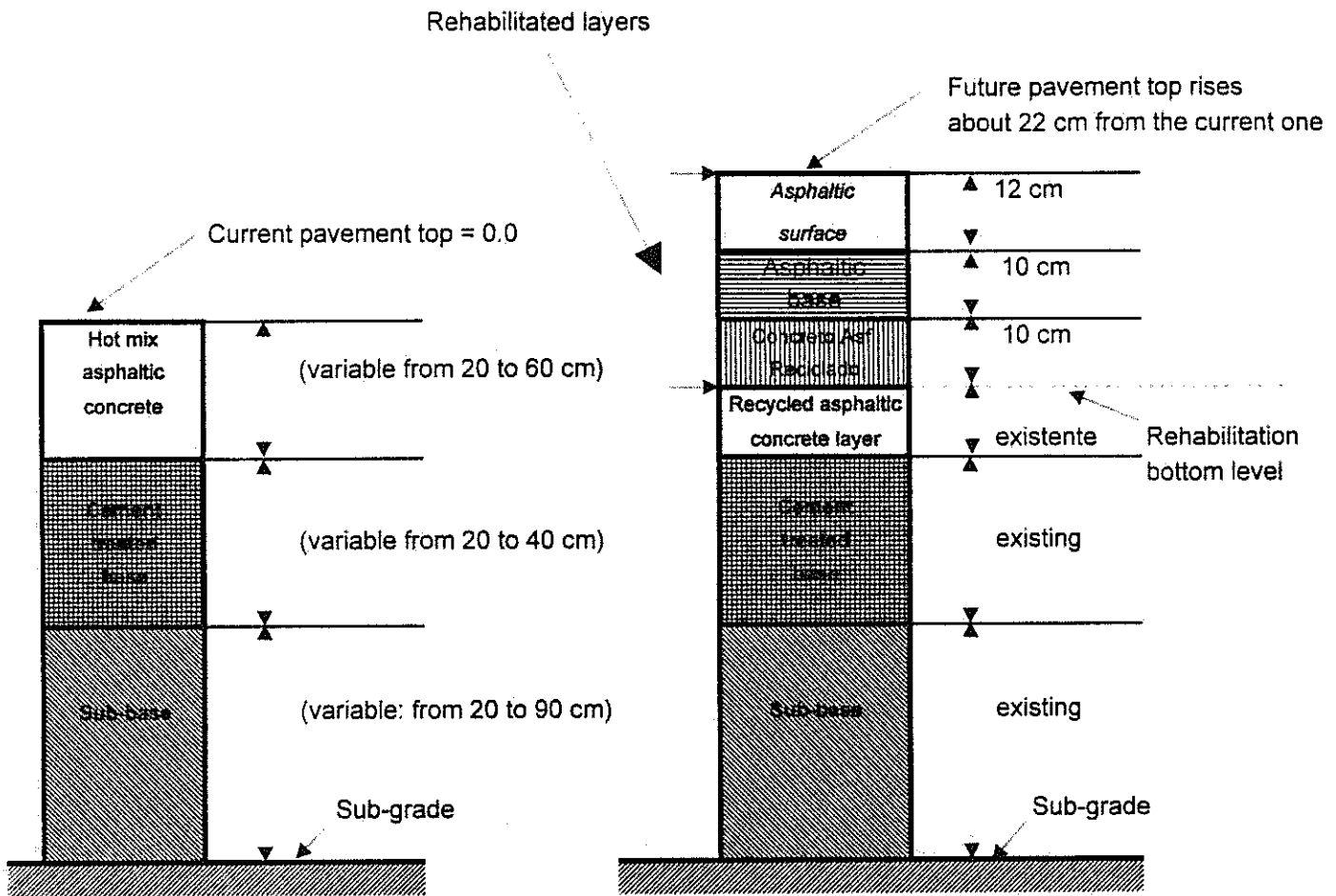
Figure 6.1 presents this option structural details.

6.3.2 Taxi way rehabilitation alternative

Figures 6.2 to 6.5 show all cross sections for every rehabilitation alternative previously proposed:

- Cement treated base recycling and overlaying (Figure 6.2).

FIGURE 6.1: Run Way rehabilitation alternative (recycling and overlays).



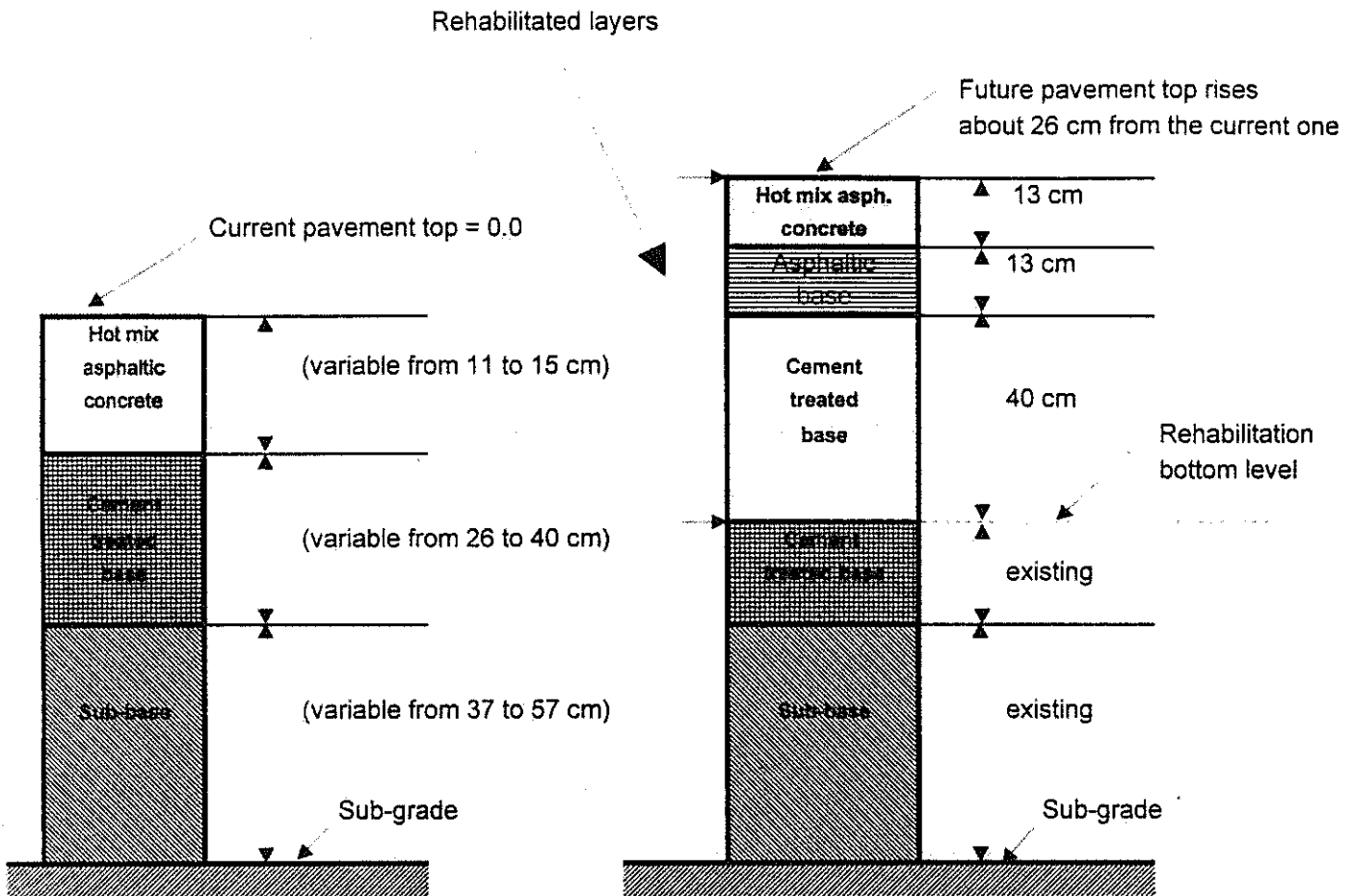
EXISTING PAVEMENT

The existing pavement total thickness from 80 to 135 cm.

REHABILITATION ALTERNATIVE

- Recycle top 10 cm asphaltic surface
- Place a 10 cm thick asphaltic surface
- Place a 12 cm thick asphaltic surface

FIGURE 6.2: Taxy way rehabilitation alternative No. 1 (Flexible pavement)



EXISTING PAVEMENT

REHABILITATION ALTERNATIVE

- Remove top 40 cm and place an cement treated base
- Place a 13 cm thick asphaltic base
- Place a 13 cm thick asphaltic surface

- Rigid pavement reconstruction (Figure 6.3).
- Sub-grade injection (Figure 6.4).
- Sub-base injection (Figure 6.5).

In addition, there is a fifth alternative which consists of both sub-grade and sub-base injection. In this case, the rehabilitation alternative is the same as it was proposed for a sub-base injection, except that the required cement treated base thickness is reduced to 27 cm.

6.3.3 External gate areas pavement rehabilitation alternative

Taxi way rehabilitation alternatives are also valid here, except that the existing pavement removal has to be at least 60 cm thick (alternative 2), in order for the new pavement top level not to be too much higher than the current one, since in such a case it would rise up only 6 cm.

It is a fact that further laboratory and field testing have to be conducted, in order to trully determine whether the sub-grade CBR is higher than 3 % or not. Should the sub-grade CBR be found to be higher than 3 %, the pavement thickness decreases.

6.3.4 Rehabilitation alternatives for pavement areas between gates

Alternative 1: crack sealing and overlay. Therefore it is required to:

- Place an asphaltic seal.
- Place a membrane-type asphaltic layer (2.5 cm thick).
- Place a 7 cm thick asphaltic mix overlay.

Alternative 2: Reconstruction from sub-base level up. The procedure to follow is:

- Asphaltic surface and base removal (40 cm).
- Place a 29 cm cement treated base, stabilizing existing removed materials.
- Build a 8 cm thick asphaltic base.
- Build a 8 cm thick asphaltic surface.

6.3.5 New pavement construction alternatives

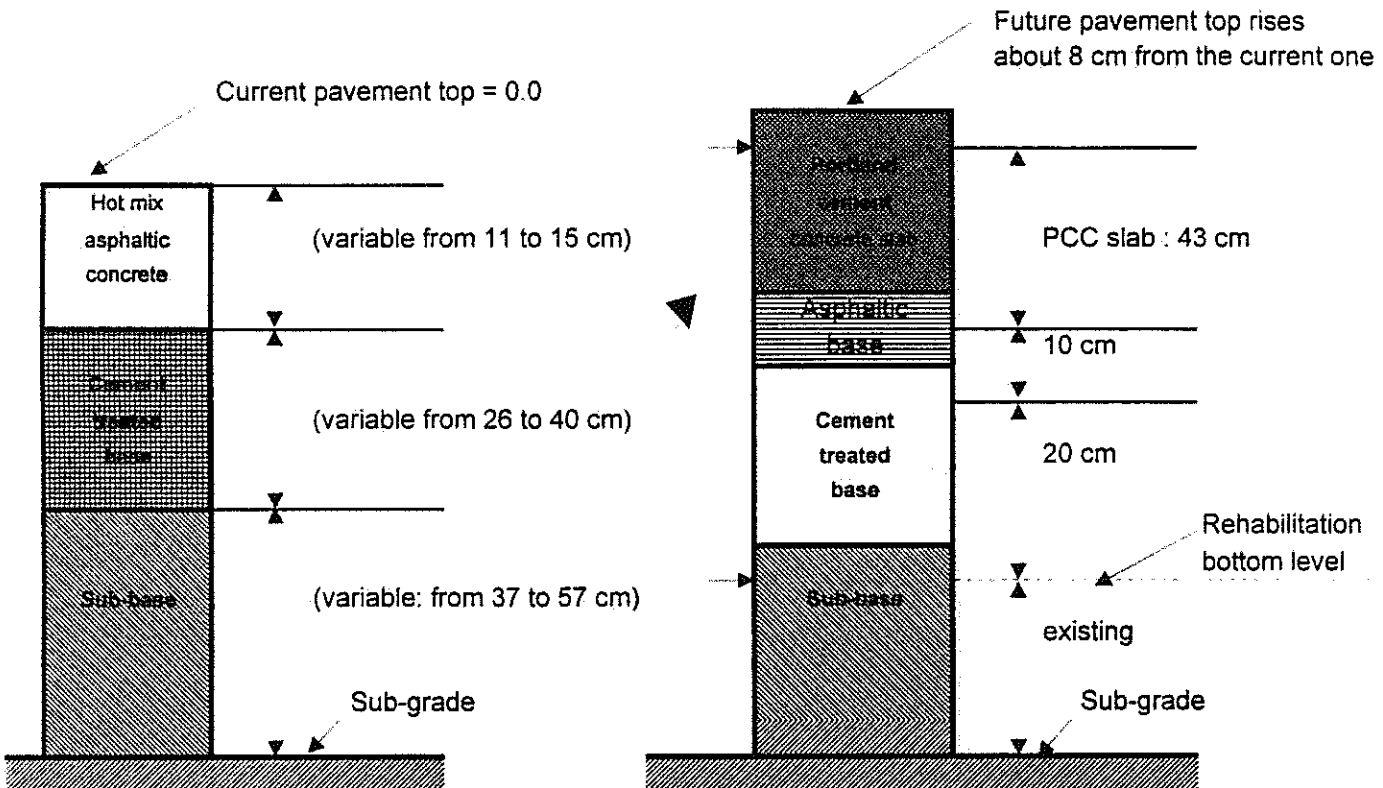
Figures 6.6 to 6.8 show pavement cross sections corresponding to:

- Flexible pavement with a granular base (Figure 6.6).
- Flexible pavement with an asphaltic base (Figure 6.7).
- Rigid pavement (Figure 6.8).

In all these construction alternatives, the sub-grade CBR is 5 %.

FIGURE 6.3: Taxy way rehabilitation alternative No. 2 (Rigid pavement)

Rehabilitated layers



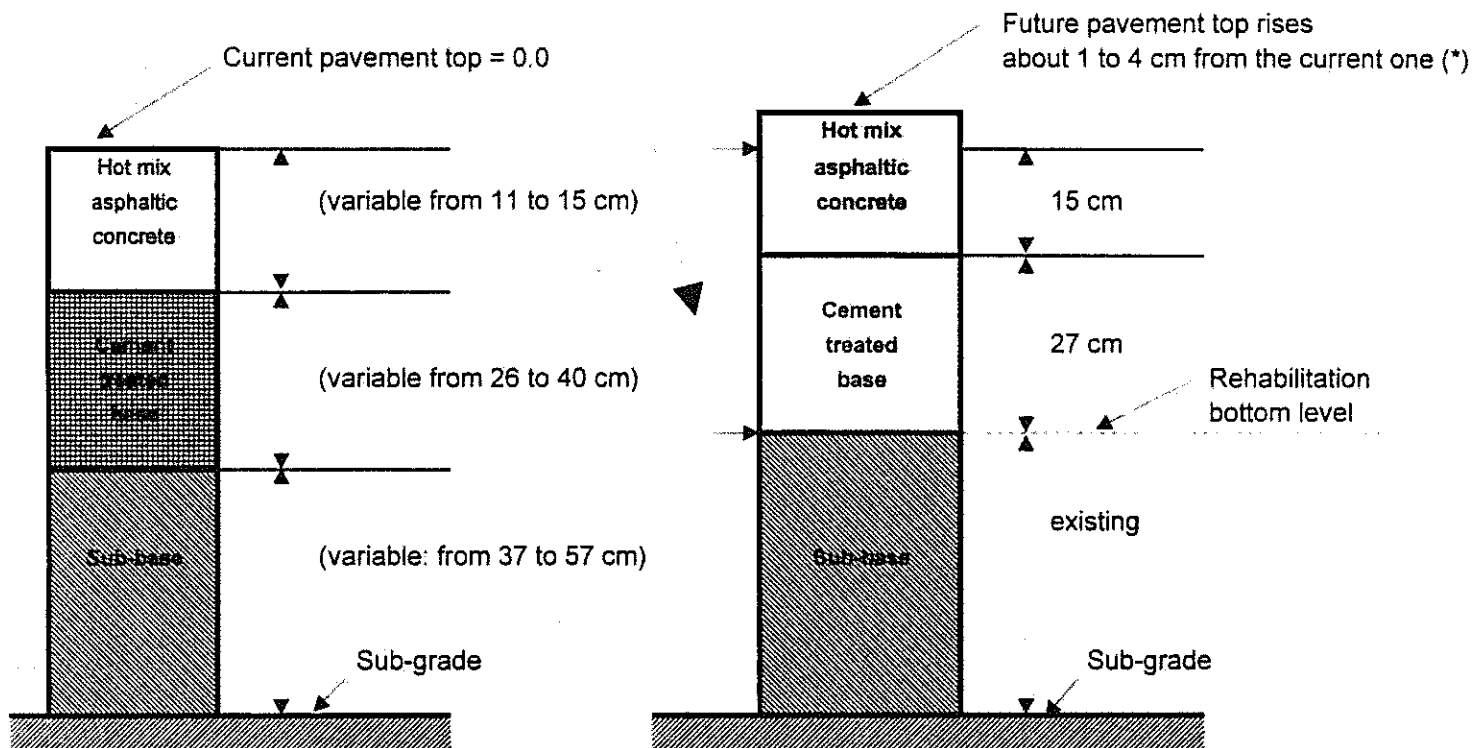
EXISTING PAVEMENT

REHABILITATION ALTERNATIVE

- Remove top 65 cm existing pavement
- Re-Compact existing sub-base
- Place a 20 cm thick treated base
- Place a 10 cm thick asphaltic base
- Build a 43 cm thick PCC slab

FIGURE 6.4: Taxy way rehabilitation alternative No. 2 (Sub-grade injection)

Rehabilitated layers



EXISTING PAVEMENT

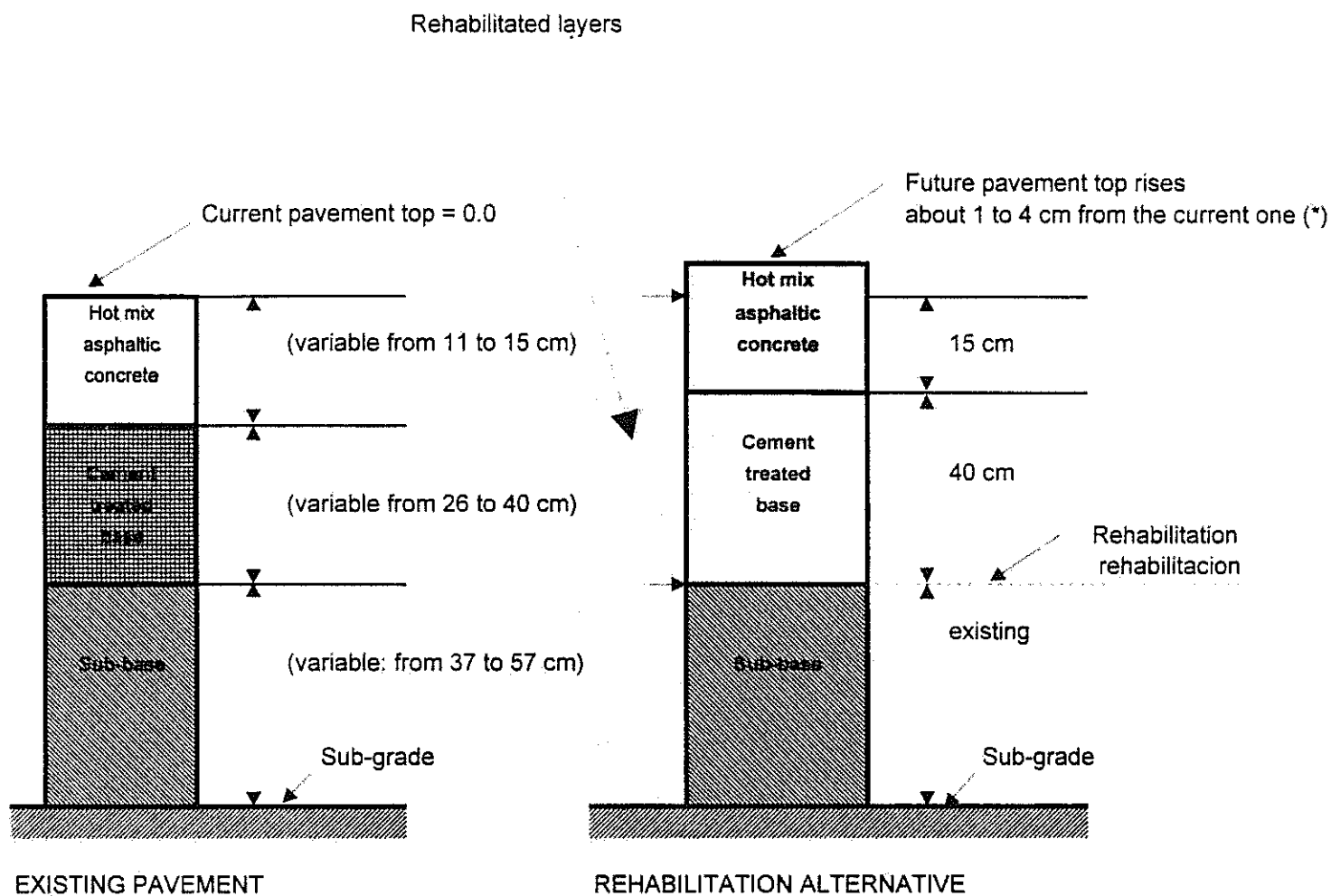
REHABILITATION ALTERNATIVE

- Asphaltic surface removal (possible recycling)
- Remove and stabilize the top 26 cm current base material
- Place a new 15 cm asphaltic surface

Note: the asphaltic surface and treated base may be removed and stabilized. In such case the pavement top rises 15 cm up.

(*) Due to the high variability among current asphaltic surface thicknesses.

FIGURE 6.5: Taxy way rehabilitation alternative No. 4 (Sub-base injection)

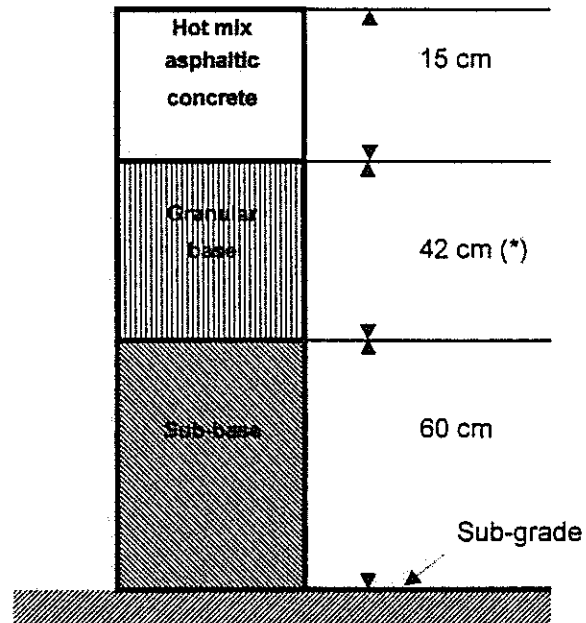


- Sub-base injection until reaching a resilient modulus of 20000 kg/cm² (284000psi)
- Remove existing asphaltic surface, possible recycling operation
- In site base cement stabilization (40 cm)
- New 15 cm thick asphaltic surface

Note: as it was previously suggested, it is possible to remove and re-compact the treated base, including the asphaltic surface in such case

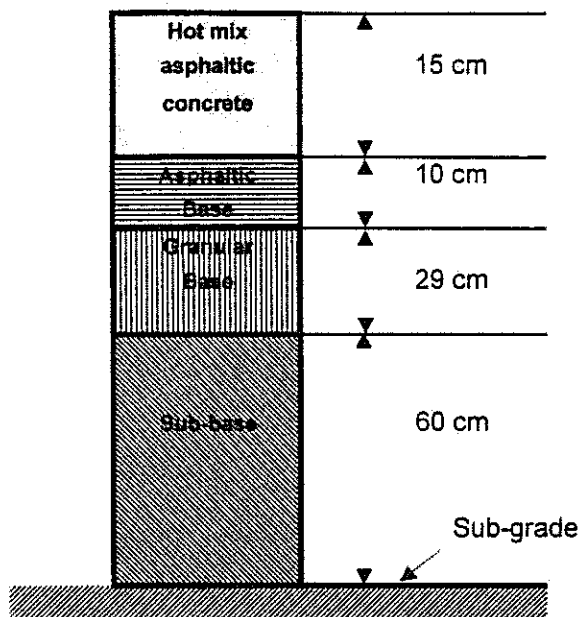
(*) Due to the high variability among current asphaltic surface thicknesses.

FIGURE 6.6: New flexible pavement, with granular base (alternative No. 1)

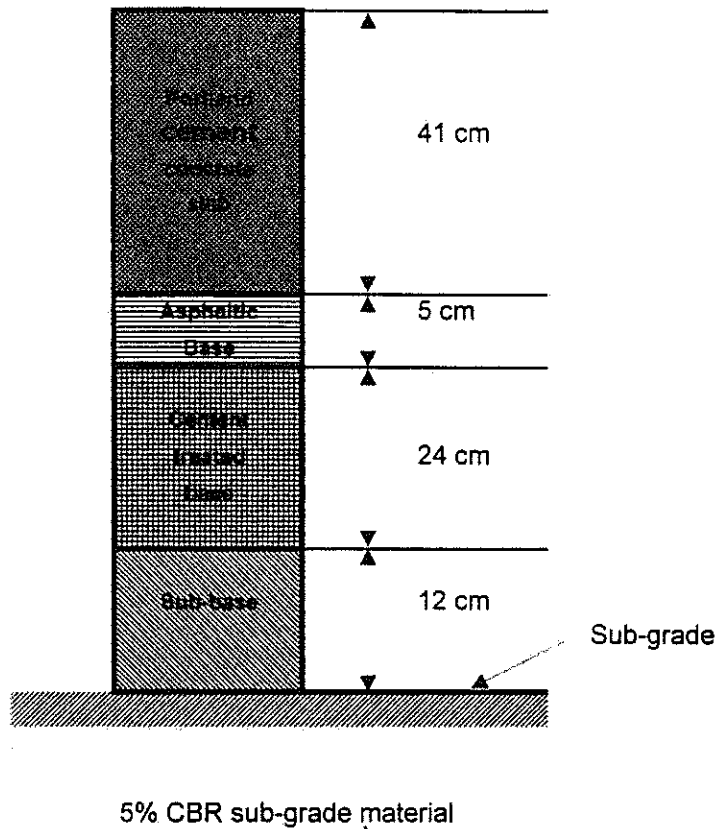


(*) This thickness may be decreased if a cement treated base is built
5% CBR sub-grade material

FIGURE 6.7: New flexible pavement, with asphaltic base (alternative No. 2)



5% CBR sub-grade material

FIGURE 6.8: New rigid pavement alternative

7. DRAINAGE

To ensure an optimum long term pavement performance, it is recommended to build lateral drains to both pavement sides, in all the pavement structure. Also, there has to be an efficient transversal pumping system, in order to evacuate rainfall, conducting it to reception tanks.

Draining pipes must be located at least 50 cm below the sub-grade level.

8. CONCLUSIONS

1- It is required to gather further core extraction information, since the available information is not totally accurate on the pavement layers thicknesses, as well as on layer materials properties.

2- From the coring extraction it has been deduced that the underground water reaches a very high level into the pavement, specially in winter.

3- Should further laboratory and field testing be performed, as well as a pavement load distribution analysis, based on tire inflating pressure and landing gear configuration, the existing pavement structural analysis will become more accurate, regarding resilient moduli and layer thicknesses, and the rehabilitation alternatives are optimized. Such analysis is specially important when there is a fatigue condition on the pavement structure, as in the Juan Santamaria run way and taxi way pavement.

4- A pavement deflexion analysis would give a lot of information on the existing pavement structural ability and the pavement layers failure condition.

5- When more laboratory and field information is gathered, it will be possible to develop adjustments on the proposed rehabilitation alternatives, since it will be possible to know exactly when the existing pavement conditions change and define more accurate homogeneous sections.

6- If the finally selected rehabilitation alternative involves current pavement materials removing, crushing and/or recycling, it is necessary to have a complete laboratory support analysis on the resulting material long term properties. In addition, it is very important to practice a strict quality control during the construction process. Also, the project specifications have to include the maximum layer thicknesses that may be completed at once, since the construction equipment accuracy is reduced when thick layers are placed.

7- Asphalt concrete recycling has to be based upon laboratory analysis and quality control, before and after construction, so the long term mix quality is guaranteed.

8- In order to perform a successful rehabilitation process it is required to be certain the drainage is fully functional: surface pumping, lateral drains, major draining pipes and rainfall disposal.

9- Project specifications and quality control methodology are considered key factors to ensure the rehabilitation costs are to be paid off, and the resulting structure is able to withstand the design period load.

10- Surface cracking shows there is a fatigue problem on the asphaltic surface, due to the flexion and tension stresses on it. Therefore, it is important to build a new asphaltic surface with a modified asphalt, in order to minimize this problem, specially in the turning areas. This would increase the pavement service life and decrease maintenance related flight delays.

11- Should any injection alternative be selected as best, it will be required to build a test track, in order to ensure the expected injected layer homogeneity and stiffness.

12- In order to select the final rehabilitation procedure, it is very important to consider any impact on the airport usual transit, such as flight delays; and consider its cost.

13- The taxi way pavement failure condition, together with its lack of structural adequacy, disqualify overlaying as a rehabilitation alternative, specially under a long term performance analysis.

14- The optimum rehabilitation alternative will depend on cost, construction time and difference in surface top level from existing pavement surface layer.

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APPENDIX 1

REHABILITATION ALTERNATIVES COSTS CONSIDERATIONS

**REHABILITATION ALTERNATIVES
COST ESTIMATES**

UNIT COSTS

ITEM	UNIDAD	\$/UNIDAD
removal	m3	12,00
prime coat	m2	0,21
tack coat	m2	0,31
cleaning	m2	0,09
base re-compaction	m2	0,20
cement for base	m3 base	21,02
aggregate for base	m3 base	14,01
treated base curing	m2	0,25
asphaltic base	m3	113,00
asphaltic surface	m3	128,00
PCC slab	m3	231,00
sub-base injection	m3	39,32
sub-grade injection	m2	32,44

RUN WAY REHABILITATION

	cm	\$/m2
SURFACE REMOVAL	10,00	1,20
ASPHALTIC SURFACE RECYCLING	10,00	10,24
FIRST ASPHALTIC OVERLAY	10,00	12,80
SECOND ASPHALTIC OVERLAY	12,00	15,36
TACK COAT (3)		0,63
TOTAL		40,23

**TAXI WAY AND EXTERNAL GATE AREAS
PAVEMENT REHABILITATION**

ALTERNATIVE #1 (FLEXIBLE RE-CONSTRUCTION)

	cm	\$/m2
SURFACE REMOVAL	12,00	1,44
BASE REMOVAL	40,00	4,80
BASE STABILIZATION	40,00	8,86
TACK COAT (1)		0,31
ASPHALTIC BASE	13,00	14,69
ASPHALTIC SURFACE	13,00	16,64
TOTAL		46,74

ALTERNATIVE #2 (RIGID RE-CONSTRUCTION)

	cm	\$/m2
PAVEMENT REMOVAL	65,00	7,80
SUB-BASE RE-COMPACTION		0,20
CEMENT TREATED BASE	20,00	7,26
PRIME COAT (1)		0,31
ASPHALTIC BASE	10,00	11,30
TACK COAT (1)		0,21
PCC SLAB	43,00	99,33
TOTAL		126,41

**TAXI WAY ADDITIONAL REHABILITATION
ALTERNATIVES****ALTERNATIVE #3 (SUB-GRADE INJECTION)**

	cm	\$/m2
SURFACE REMOVAL	12,00	1,44
SUB-GRADE INJECTION		32,44
BASE REMOVAL	27,00	3,24
BASE STABILIZATION	27,00	6,13
ASPHALTIC SURFACE	15,00	19,20
TACK COAT (1)		0,31
TOTAL		62,76

ALTERNATIVE #4 (SUB-BASE INJECTION)

	cm	\$/m2
SURFACE REMOVAL	12,00	1,44
SUB-BASE INJECTION	40,00	15,73
BASE REMOVAL	40,00	2,40
BASE STABILIZATION	40,00	8,86
ASPHALTIC SURFACE	15,00	19,20
TACK COAT (1)		0,31
TOTAL		47,94

ALTERNATIVE #5 (SUB-BASE AND SUB-GRADE
INJECTION)

	cm	\$/m2
SURFACE REMOVAL	12,00	1,44
SUB-GRADE INJECTION		32,44
SUB-BASE INJECTION	40,00	15,73
BASE REMOVAL	27,00	1,62
BASE RE-COMPACTION	27,00	6,13
ASPHALTIC SURFACE	15,00	19,20
TACK COAT (1)		0,31
TOTAL		75,25

GATE AREAS PAVEMENT REHABILITATION

ALTERNATIVE #1 (ASPHALTIC SEAL AND
MEMBRANE-TYPE ASPHALTIC LAYER)

	cm	\$/m2
ASPHALTIC SEAL		0,31
THIN ASPHALTIC LAYER	2,50	3,20
ASPHALTIC OVERLAY	7,00	8,96
PRIME COAT (1)		0,21
TOTAL		12,68

ALTERNATIVE #3 (PAVEMENT RE-CONSTRUCTION)

	cm	\$/m2
PAVEMENT REMOVAL	40,00	4,80
SUB-BASE RE-COMPACTION		0,20
BASE STABILIZATION	29,00	6,55
ASPHALTIC BASE	8,00	9,04
ASPHALTIC SURFACE	8,00	10,24
TACK COAT (1)		0,31
PRIME COAT (1)		0,21
TOTAL		31,35

Note: drainage costs (not included) are common to
all rehabilitation alternatives.

APPENDIX 2

PAVEMENT HOMOGENUOUS SECTIONS, BASED ON COMMON

FAILURE PATTERNS

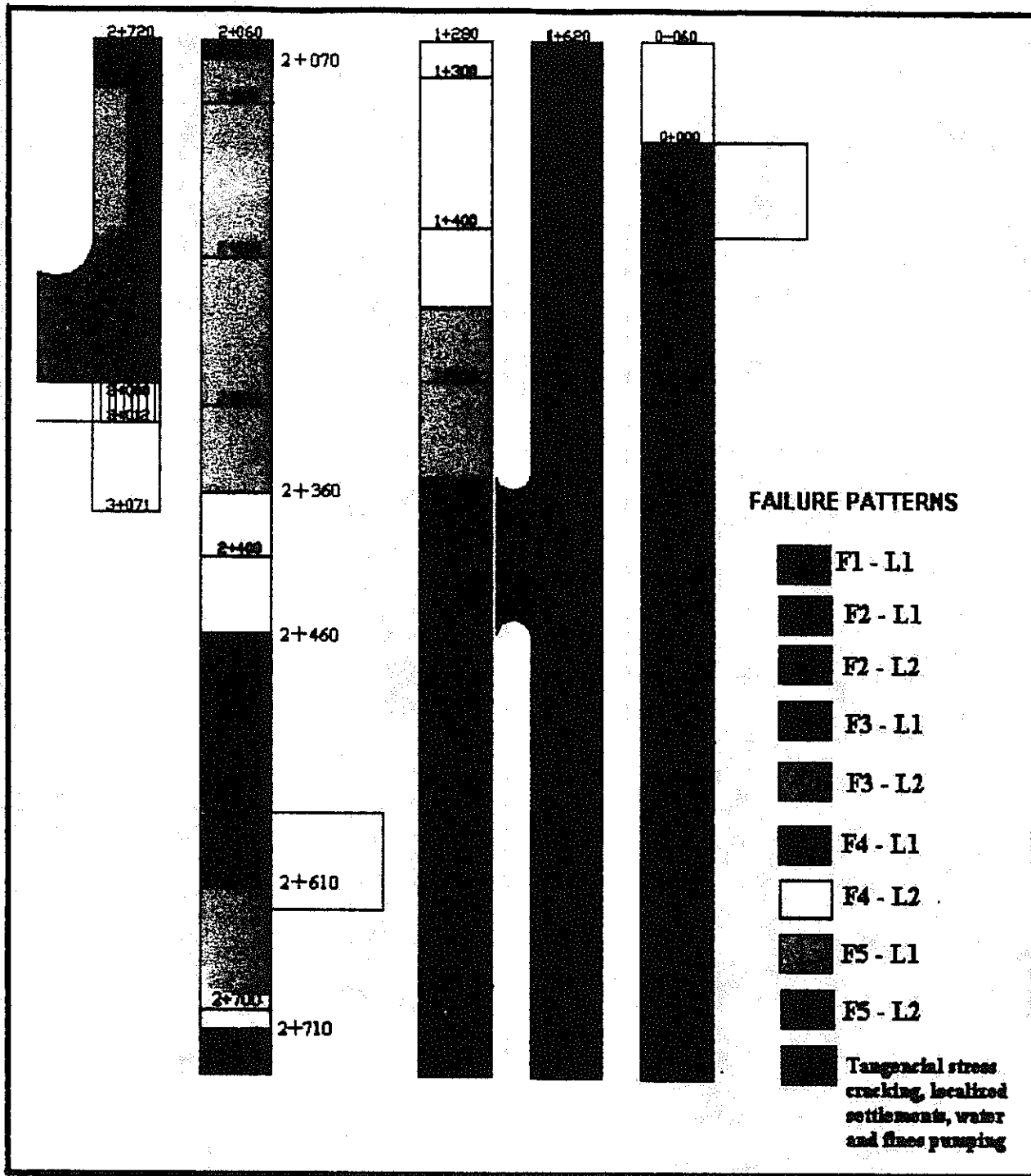


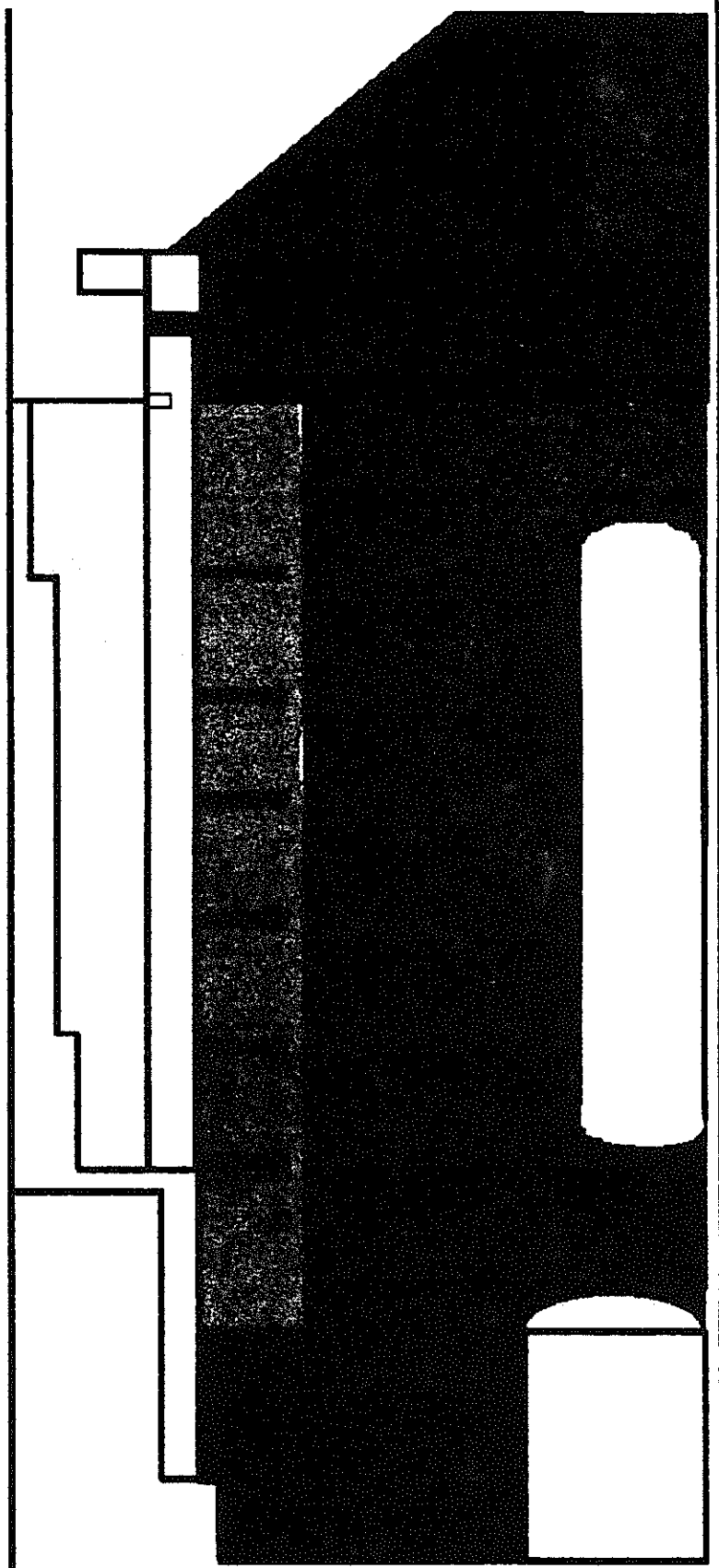
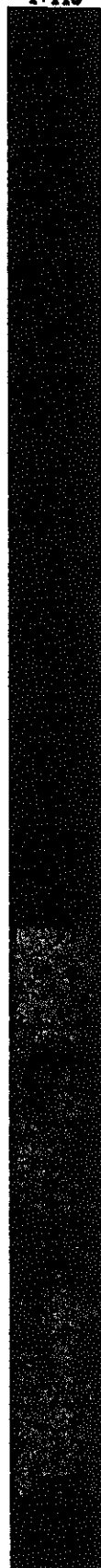
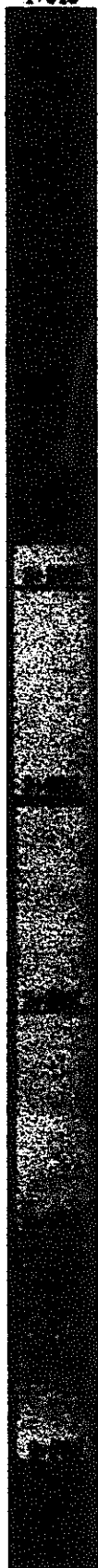
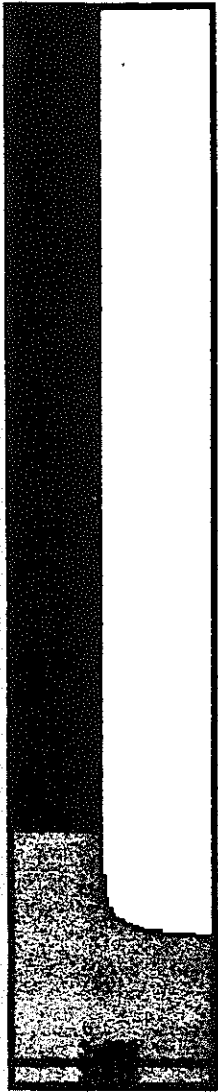
Fig. No. A2-1: Run way homogeneous sections, by typical failure patterns.

2+850

1+810

1+110

40



FAILURE PATTERNS






-  F2 - L1
-  F2 - L2
-  F4 - L2
-  F5 - L1
-  F5 - L2

Fig. No. A2-2: Taxi way and gates areas homogenous sections, by typical failure patterns.

APPENDIX 3
DESIGN CHARTS

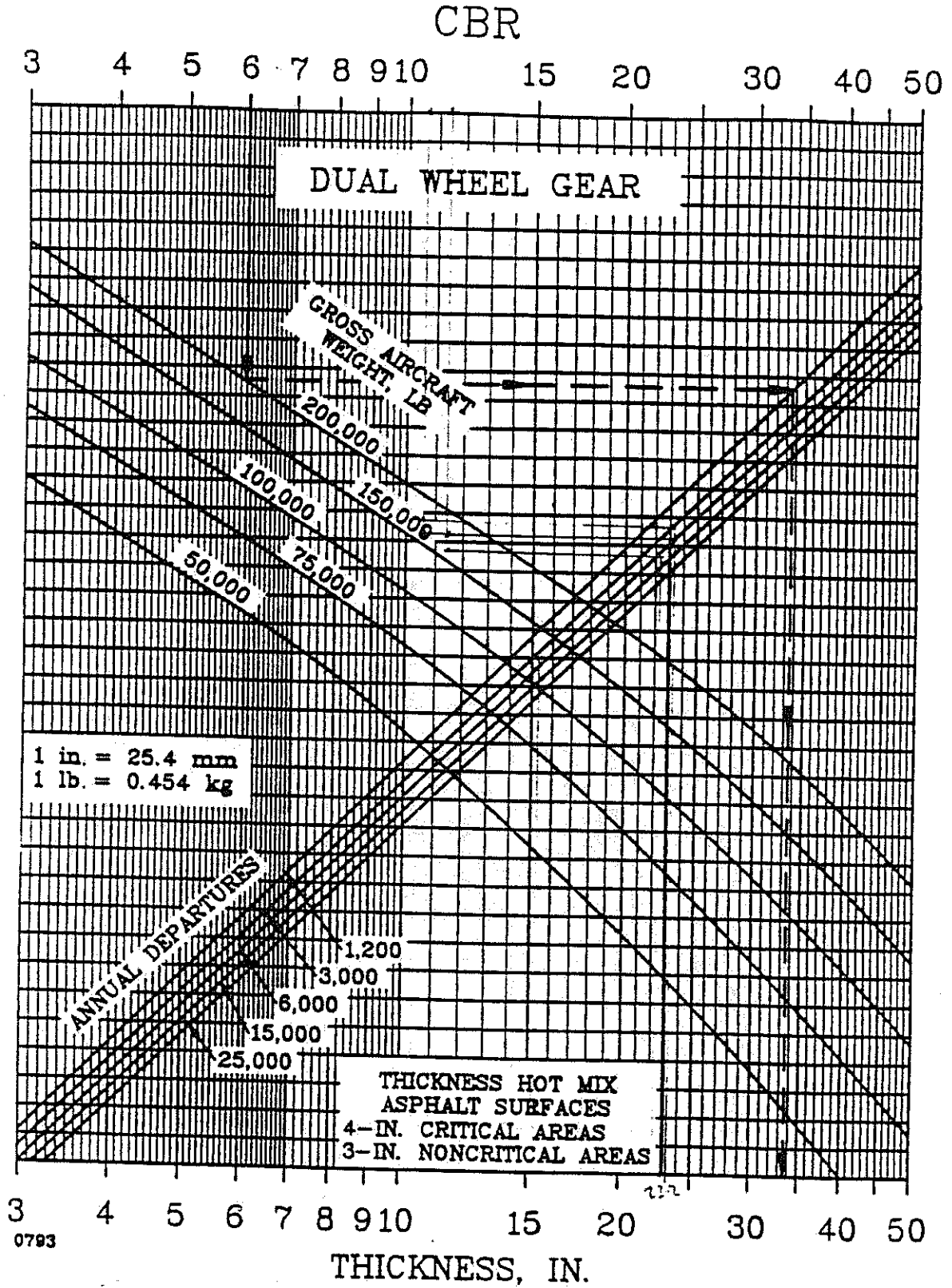


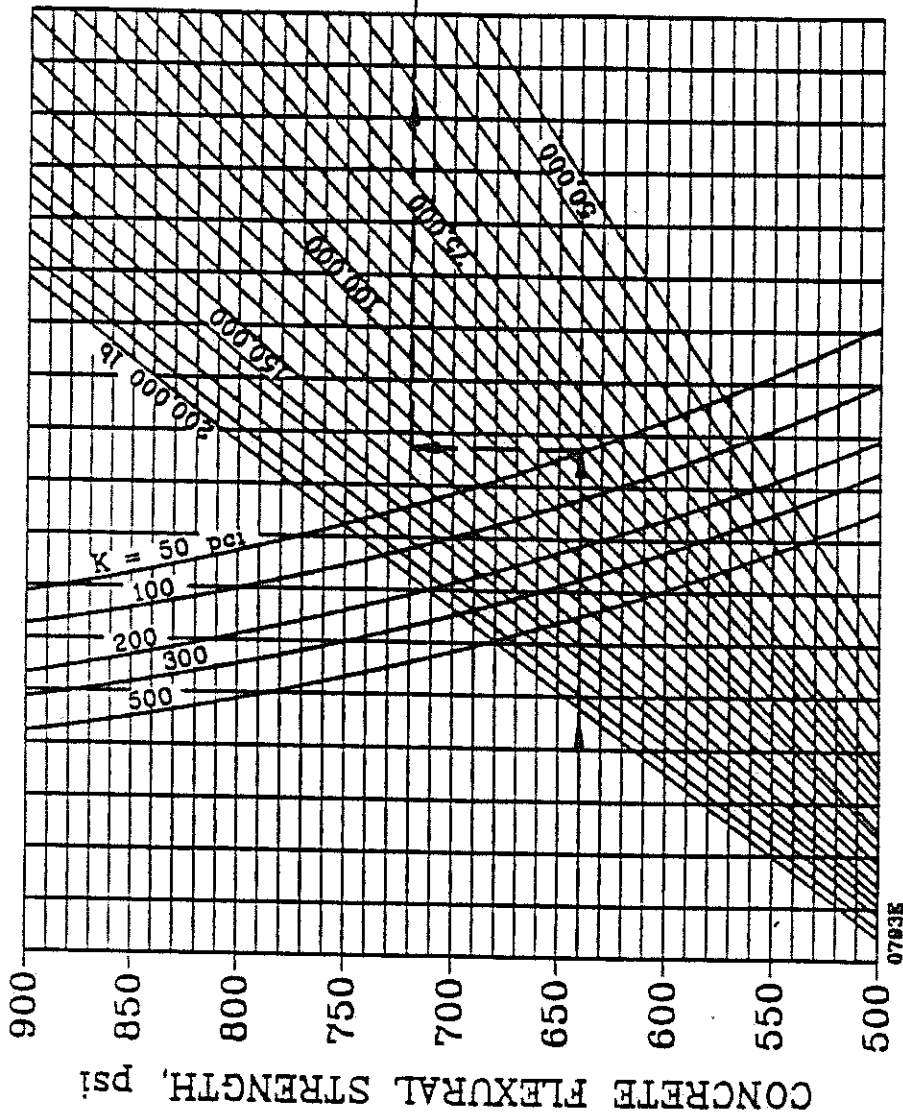
FIGURE 3-3 FLEXIBLE PAVEMENT DESIGN CURVES, DUAL WHEEL GEAR

DUAL WHEEL GEAR

ANNUAL DEPARTURES

1,200	3,000	6,000	15,000	25,000
22	23	24	26	27
21	22	23	25	26
20	21	22	24	25
19	20	21	23	24
18	19	20	22	23
17	18	19	21	22
16	17	18	20	21
15	16	17	19	20
14	15	16	18	19
13	14	15	17	18
12	13	14	16	17
11	12	13	15	16
10	11	12	14	15
9	10	11	13	14
8	9	10	12	13
7	8	9	11	12
7	7	8	10	11
7	7	8	9	10
7	7	8	8	9
7	7	7	8	8
7	7	7	7	8

SLAB THICKNESS, in



NOTE:

1 inch = 25.4 mm 1 psi = 0.0069 MN/m²
 1 lb = 0.454 kg 1 pci = 0.272 MN/m³

FIGURE 3-18. RIGID PAVEMENT DESIGN CURVES, DUAL WHEEL GEAR

APPENDIX 4
TYPICAL FAILURE PATTERNS

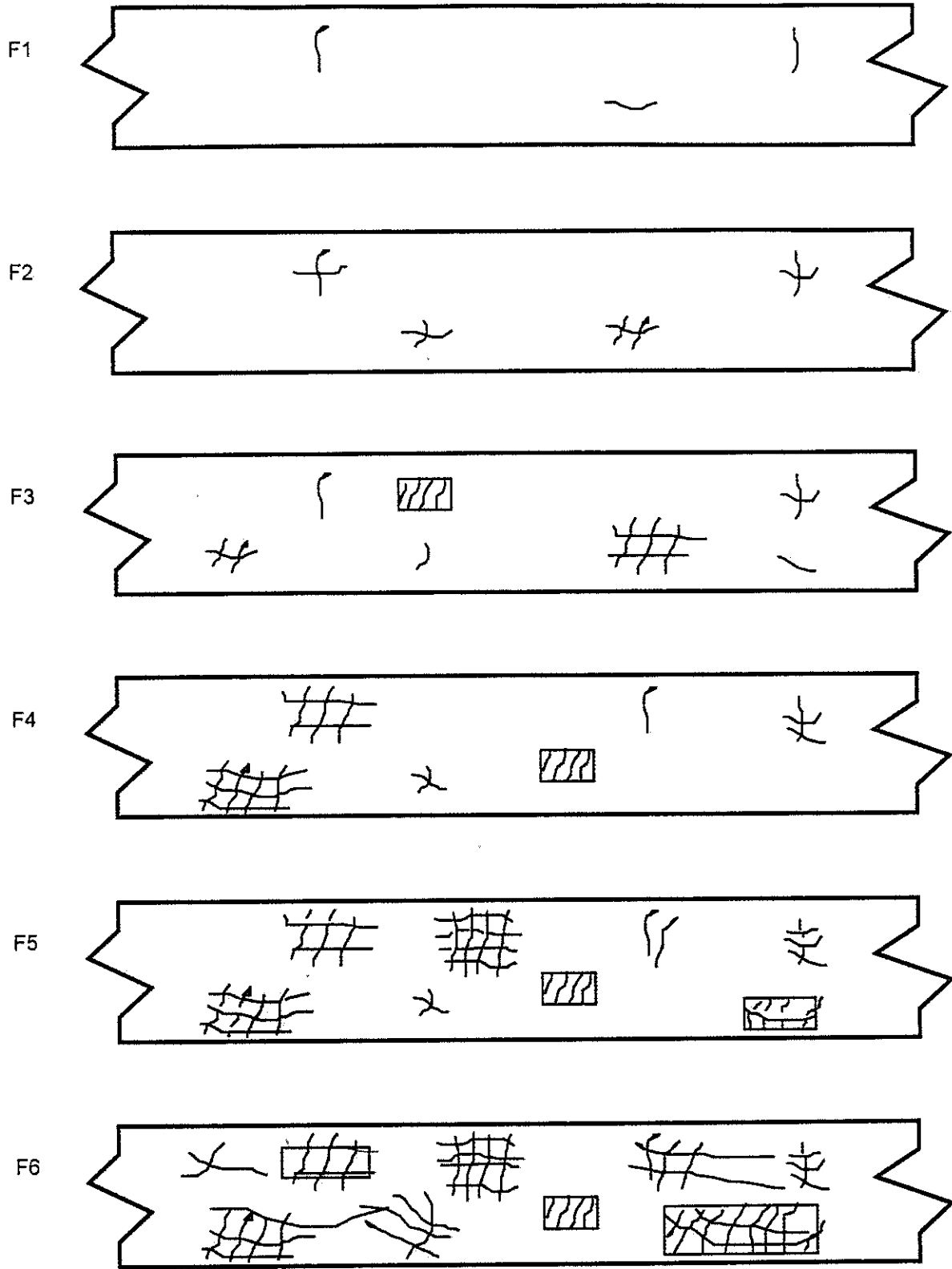


Figure No. A1-1 : Typical failure patterns.