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Design and Construction of Airport Concrete Pavement in JAPAN

Yukitomo TSUBOKAWA, Dr. Eng.
National Institute for Land & Infrastructure Management
Ministry of Land, Infrastructure, Transport & Tourism, JAPAN

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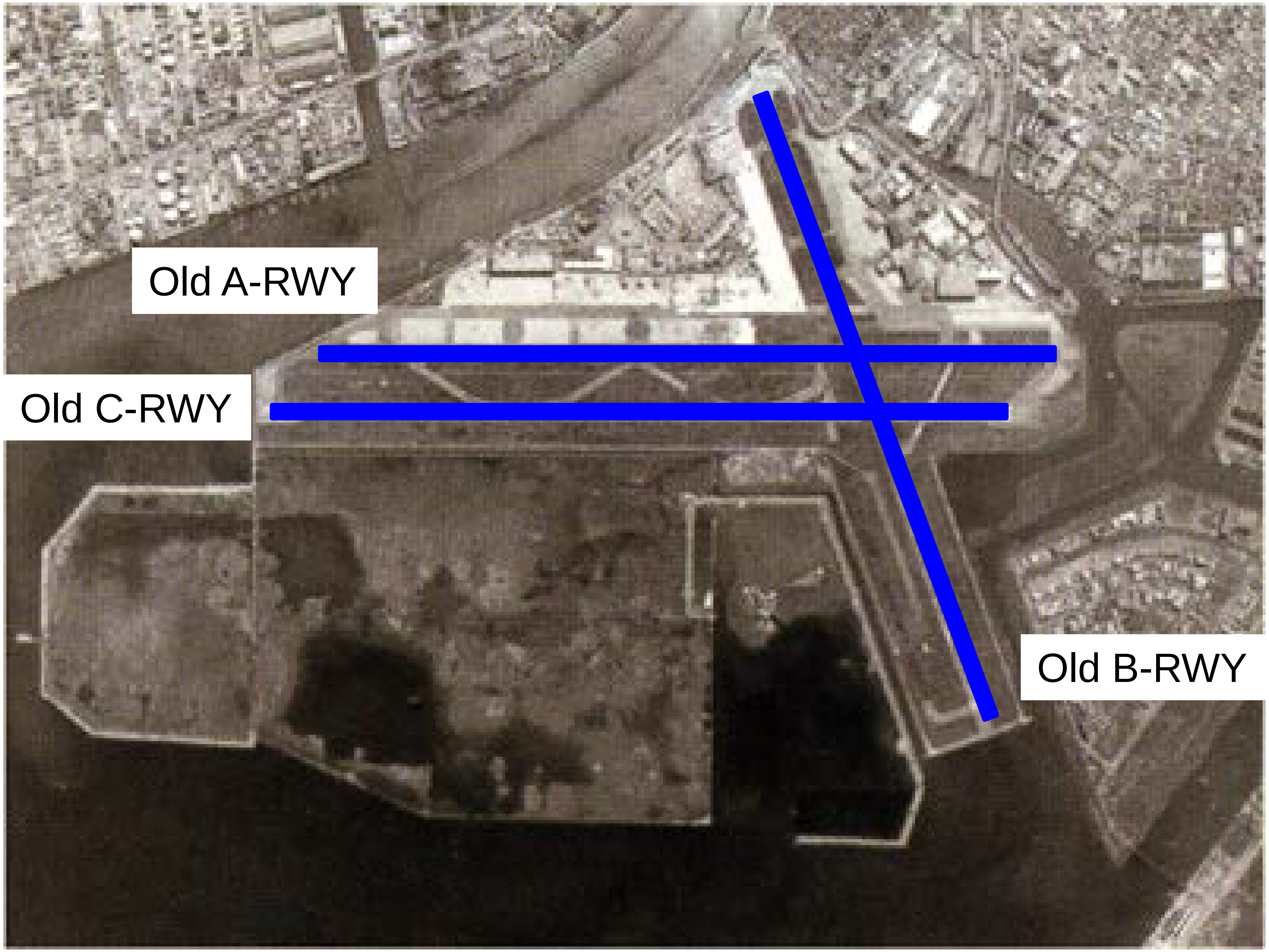
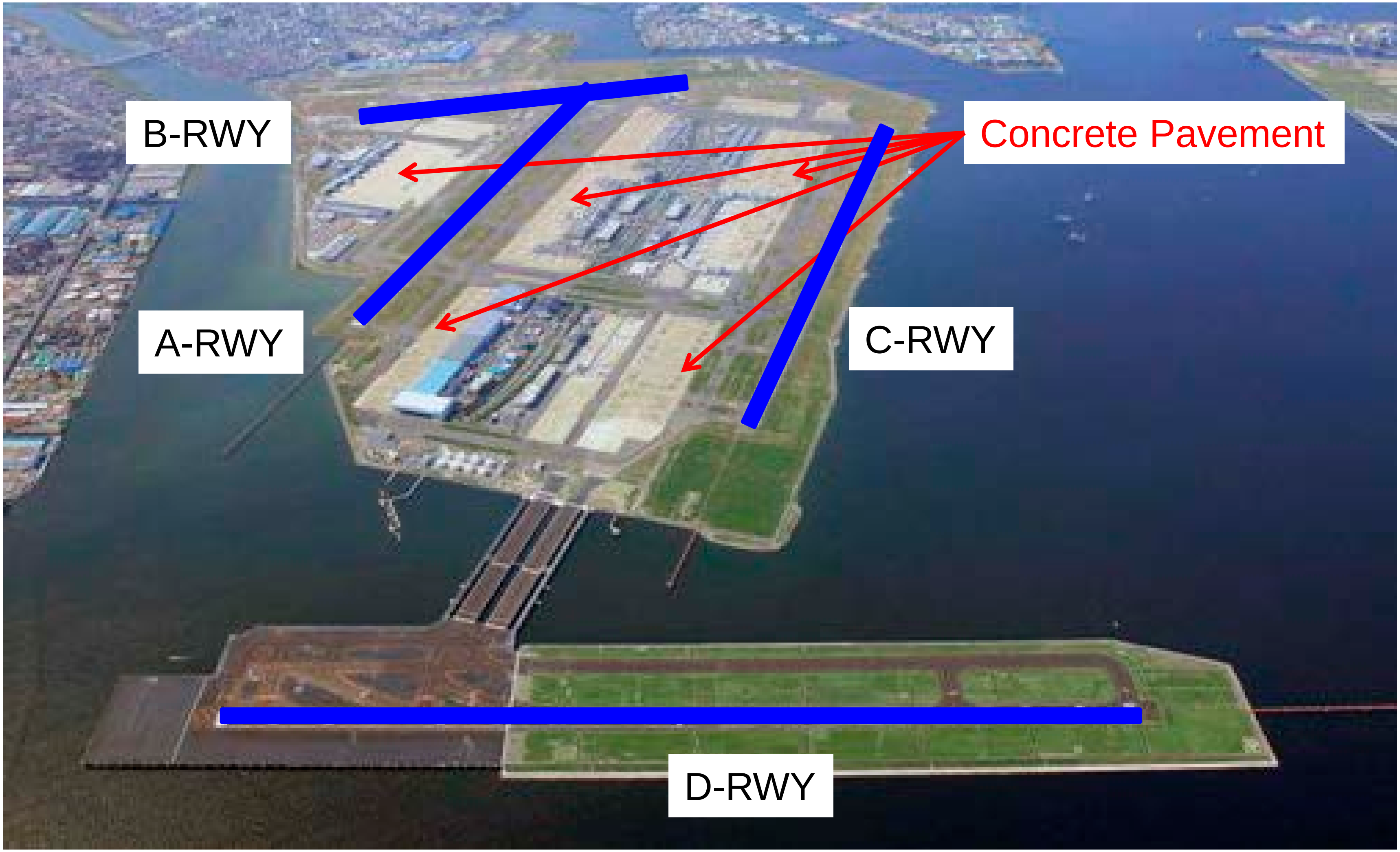
Summary of Airport Concrete Pavement



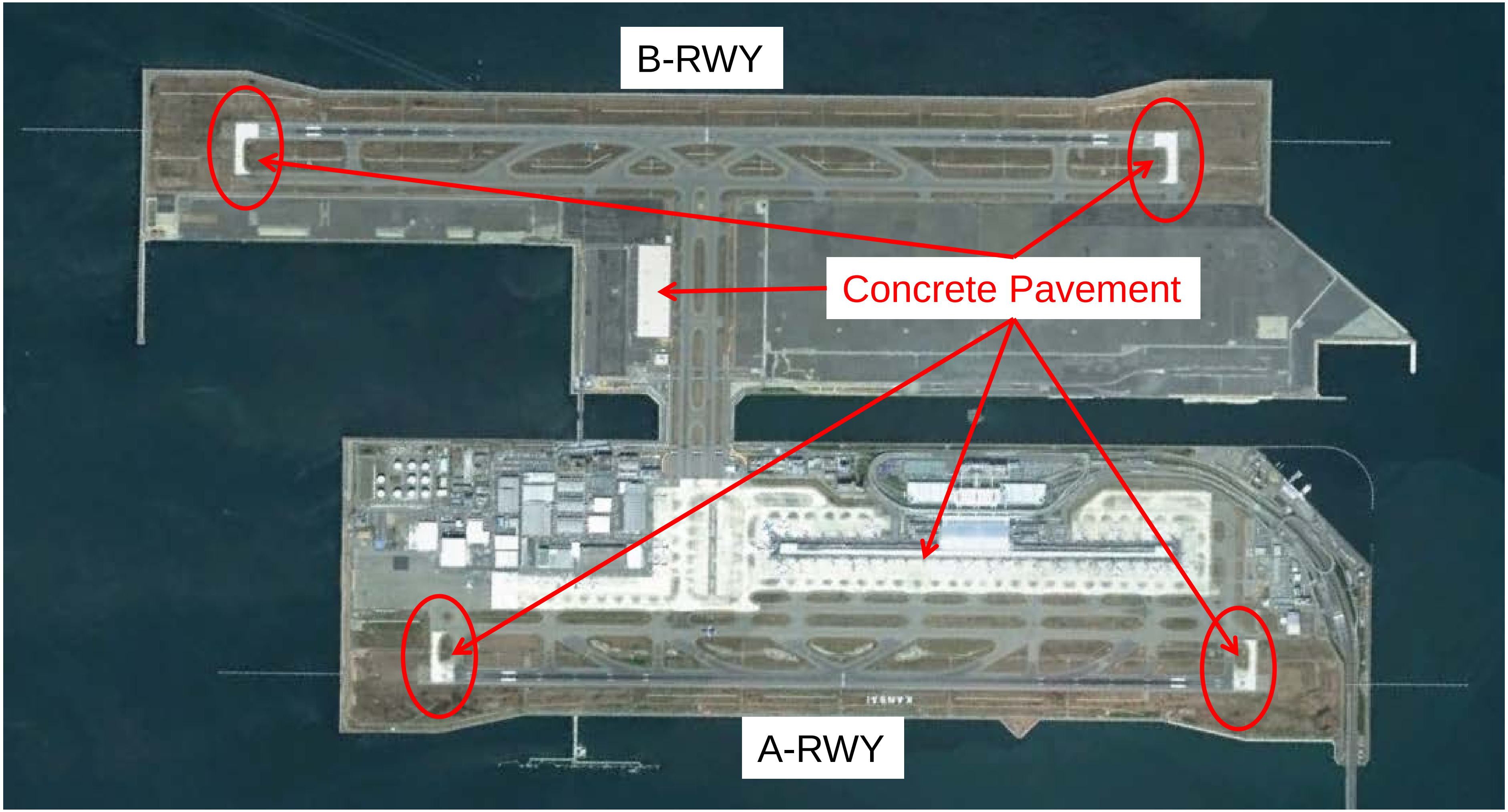
Tokyo International (Haneda) Airport
(offshore extension project in 1980’s)

Summary of Airport Concrete Pavement



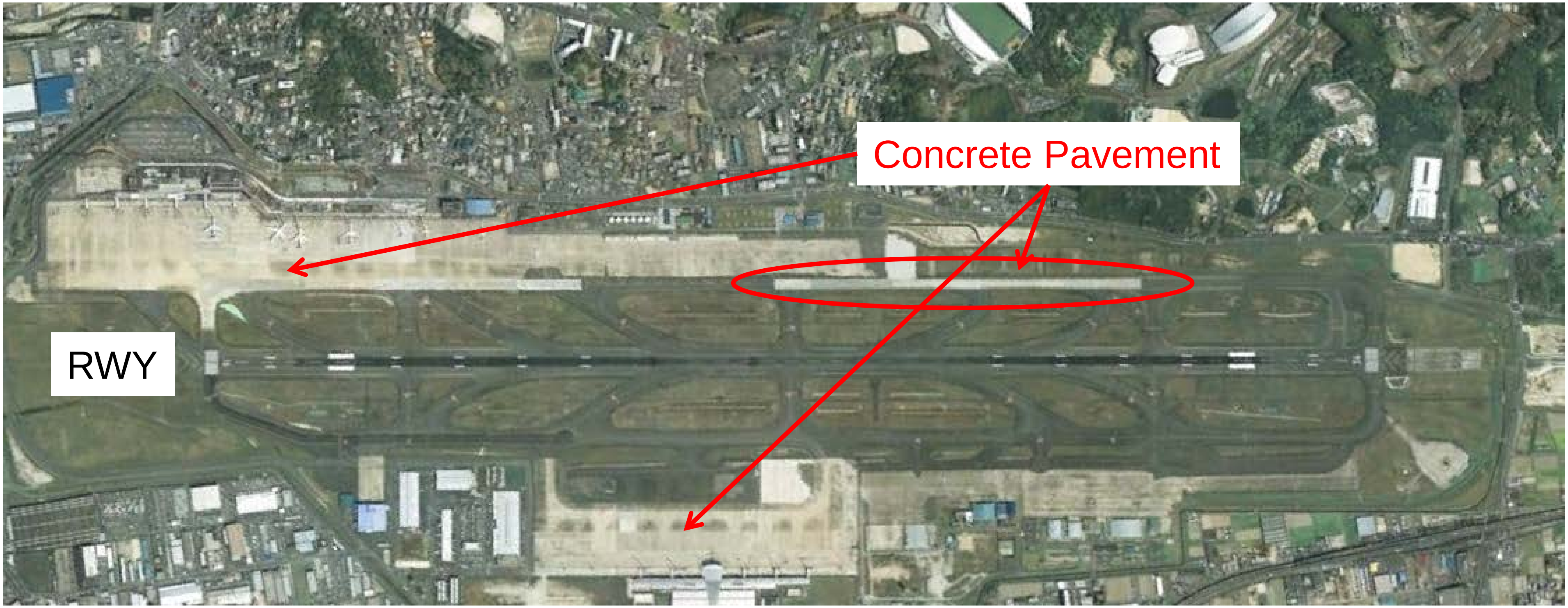
Tokyo International (Haneda) Airport
(Aprons are concrete pavement)

Summary of Airport Concrete Pavement



Kansai International Airport
(Aprons and ends of runways are concrete pavement)

Summary of Airport Concrete Pavement



Fukuoka Airport
(Aprons and a part of taxiway are concrete pavement)

Summary of Concrete Pavement

Asphalt pavement is used at

- runway
- taxiway
- apron for small aircraft

Concrete pavement is used at

- apron
- taxiway for large traffic
- end of runway (a few of large airports)

Pavement type is selected based on many factors such as

- objective of facilities
- initial cost (concrete > asphalt in JAPAN)
- easiness of rehabilitation
- construction condition etc…

Type of Concrete Pavement

NC - Non-Reinforced (Plain) Concrete Pavement

Almost all apron in JAPAN are NC Pavement

CRC - Continuously Reinforced Concrete Pavement

Reinforced with longitudinal steel

No transverse joint

Used in NARITA International Airport

PPC - Precast Prestressed Concrete Pavement

PRC - Precast Reinforced Concrete Pavement

Constructed in midnight -> Opened in morning

Used as rehabilitation work in busy airports

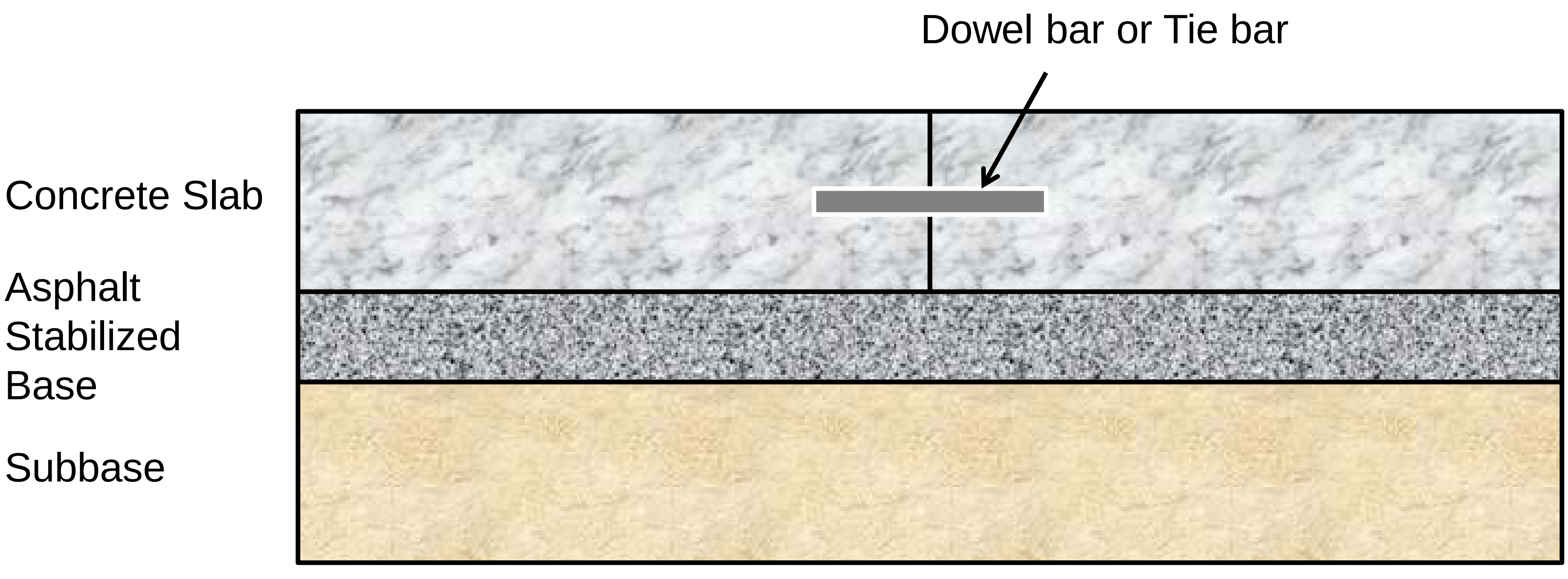
Type of Concrete Pavement

NC - Non-Reinforced (Plain) Concrete Pavement

Thickness : 37 – 45cm (for Code E and F aircraft)

Maximum joint spacing : 8.5m

Flexural strength of concrete : 5N/mm^2



Type of Concrete Pavement

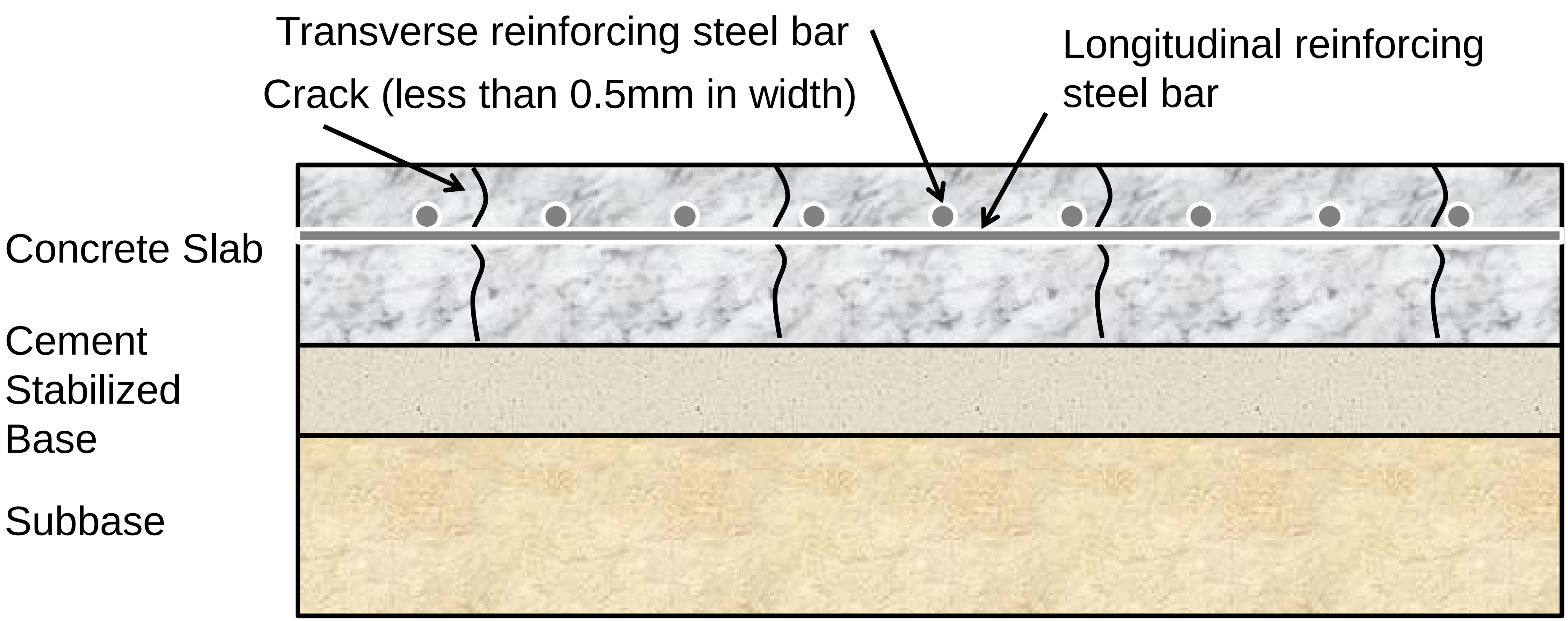
CRC - Continuously Reinforced Concrete Pavement

Thickness : 30 – 35cm (for Code E and F aircraft)

Expansion joint spacing : about 200m

Reinforcement ratio : 0.65% (longitudinal)

0.09% (transverse)



Type of Concrete Pavement

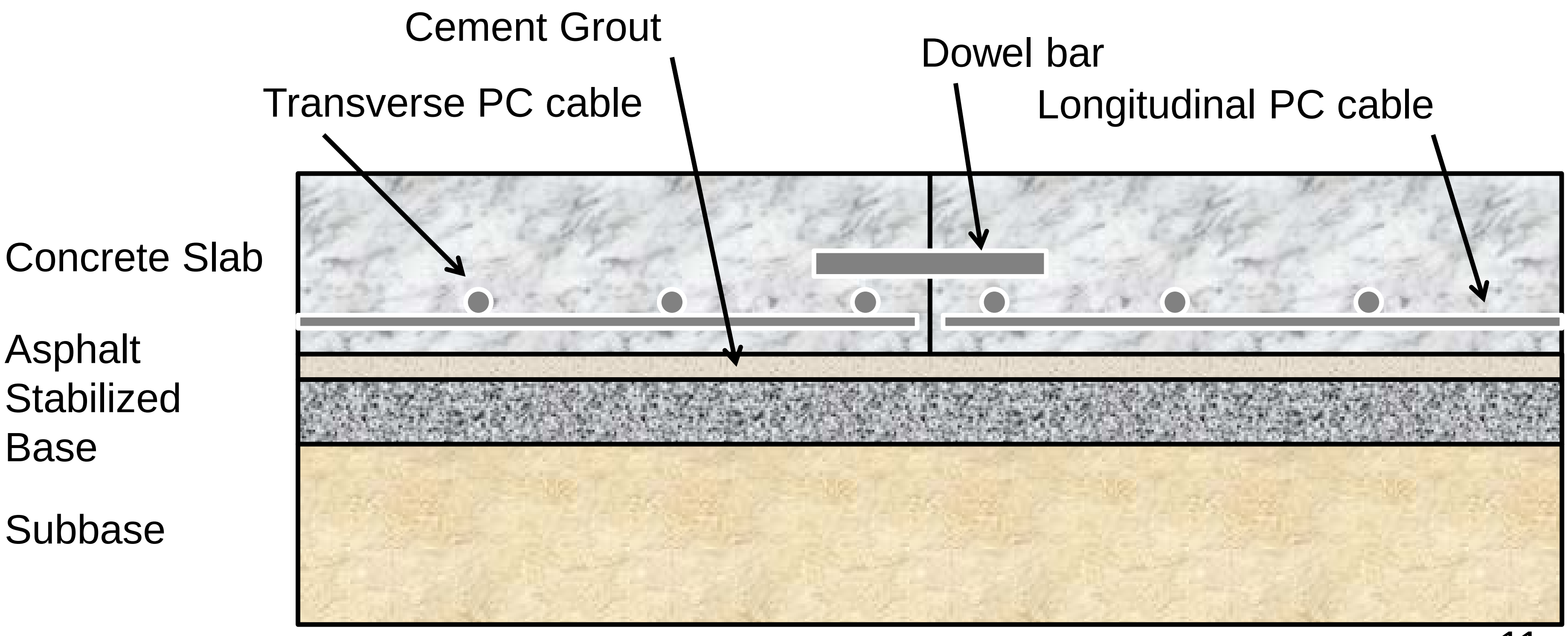
PPC - Precast Prestressed Concrete Pavement

Thickness : 24cm (for Code E and F aircraft)

Slab size : 15m x 7.5m (10m x 2.5m x 3 slabs)

PC cable : ϕ12.7mm @150 mm (longitudinal)

ϕ23.0mm @500 mm (transverse)

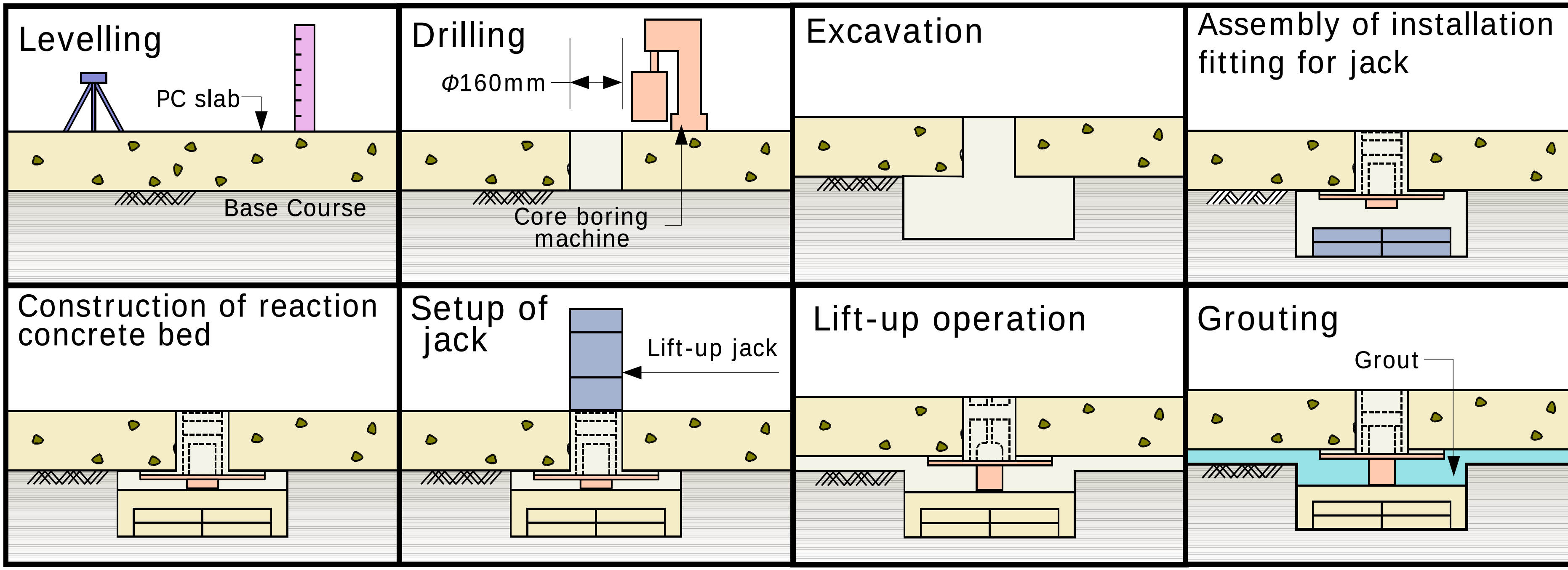


PPC Lift-Up

PPC slabs can be lifted up by the jacks and the void beneath PPC slabs is grouted.

-> Lift-up is used for rehabilitation of an apron on reclaimed land.

PPC Lift-Up



PPC is “flexible concrete slab”, Lift-up can be done.

PPC Lift-Up

Lift-up jack

Lift-up jacks are controlled by personal computer.

Type of Concrete Pavement

PRC - Precast Reinforced Concrete Pavement

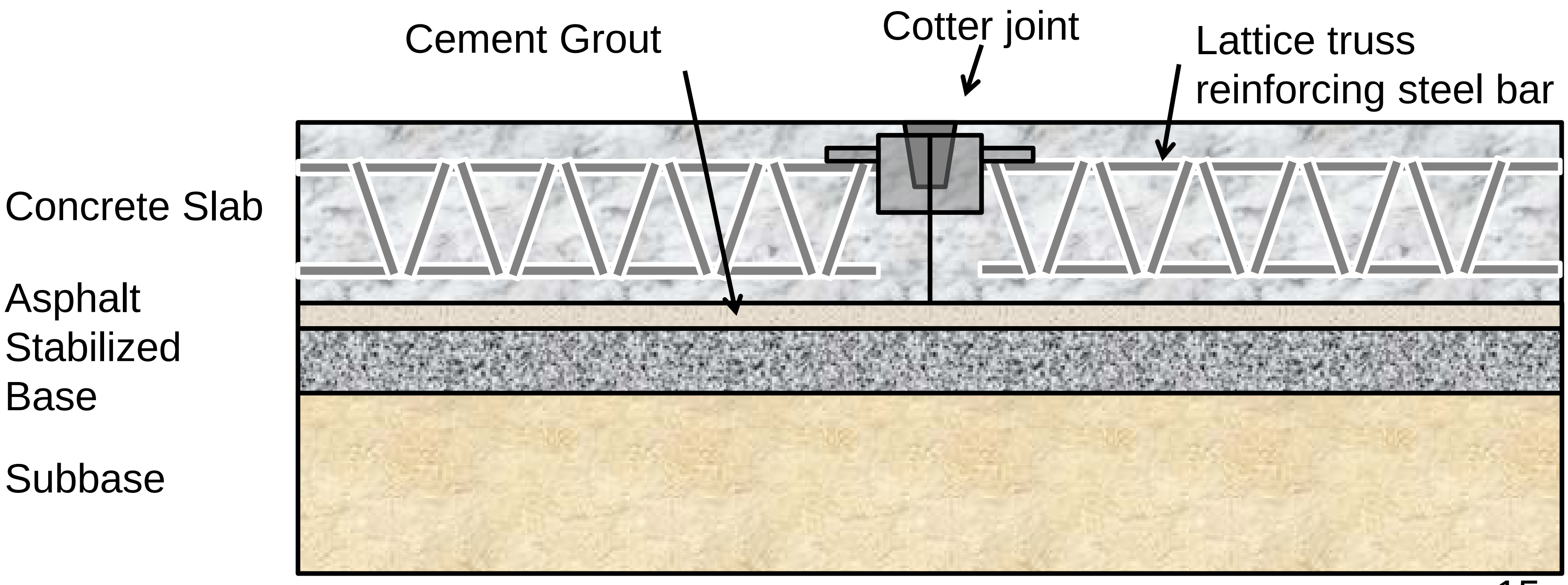
Thickness : 24cm (for Code E and F aircraft)

Slab size : 15m x 2.5m

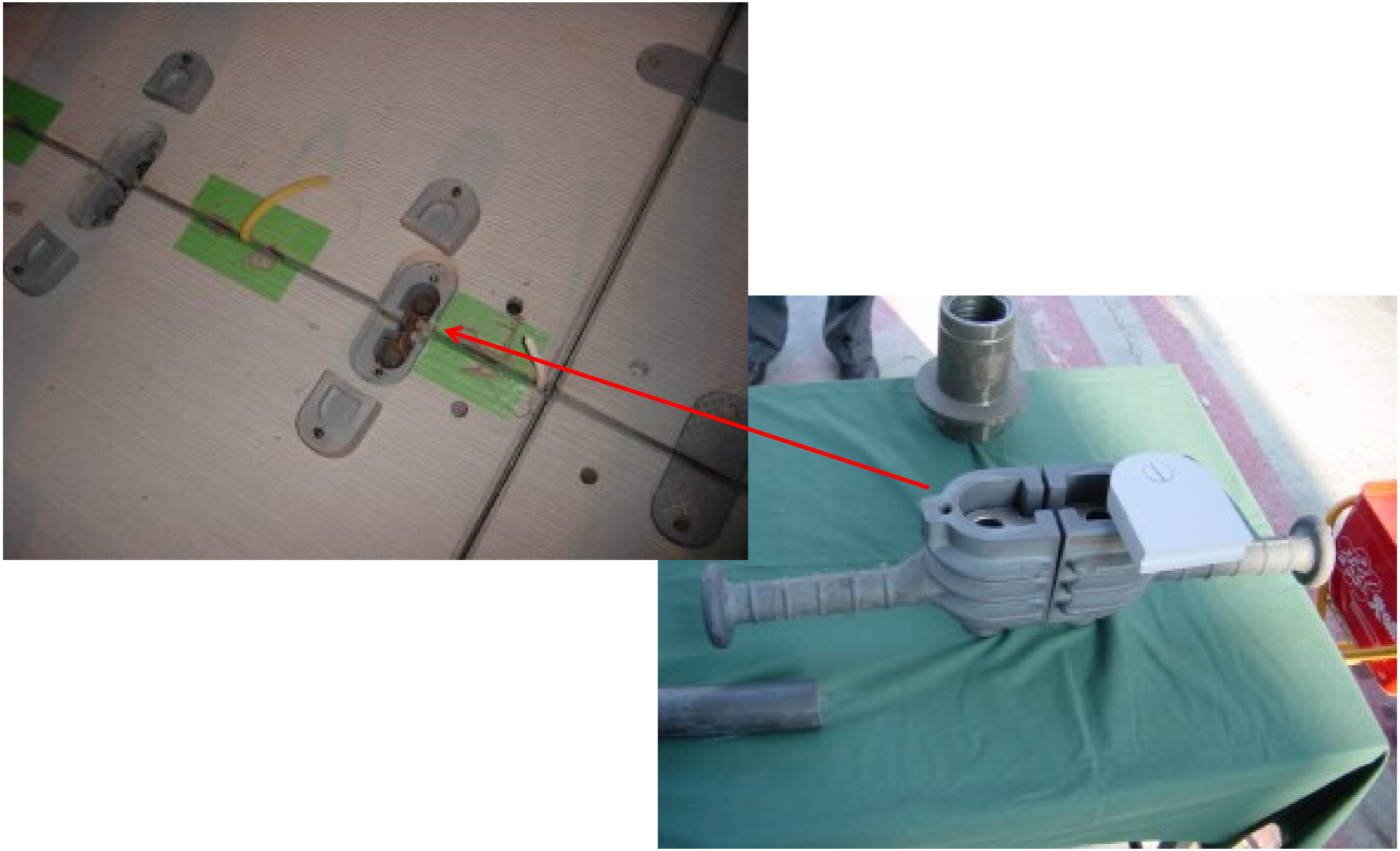
Flexural strength of concrete : 6.4N/mm^2

Reinforcing steel bar : D13 @ 75mm (upper)

D16 @ 75mm (lower)

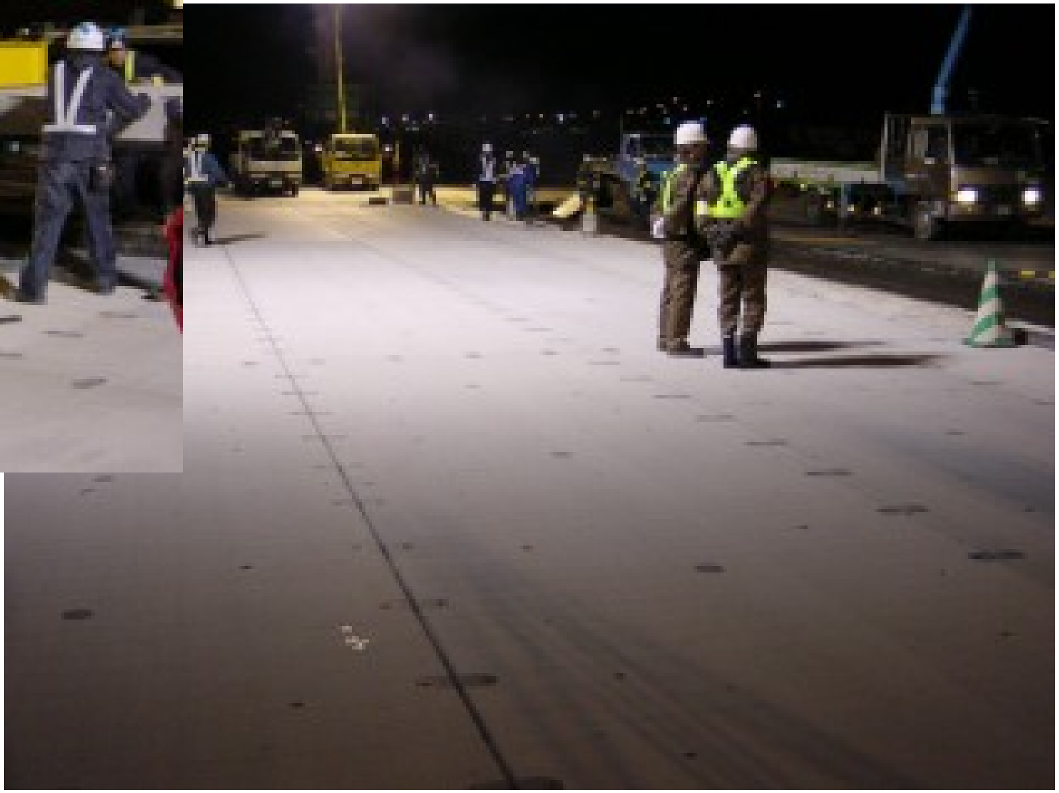


PRC



Cotter joint

PRC



Construction

Design of Concrete Pavement

Design of NC Pavement

Empirical Design Method (till 2008)

Slab thickness is designed based on loading stress.

$\sigma < f / a$

σ : loading stress at bottom of slab due to aircraft load

f : design flexural strength of concrete

a : safety factor

(=1.7 to 2.2, depending on traffic volume)

Mechanistic-Empirical Design Method (after 2008)

Slab thickness is designed based on fatigue degree due to loading stress and thermal stress.

FD : fatigue degree at bottom of slab

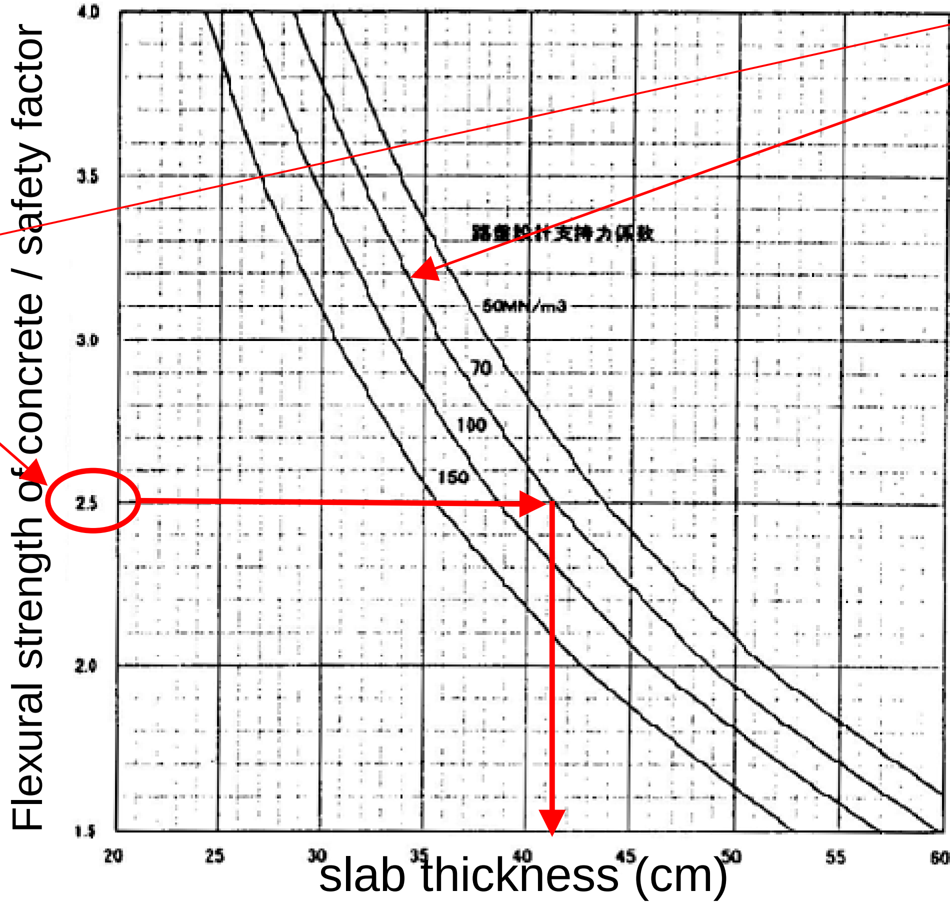
$= \Sigma(N_d / N_f)$

N_d : design number of load repetition

N_f : number of failure

Empirical Design of NC Pavement

f = 5.0N/mm^2 and safety factor = 2.0 then
σ due to aircraft load must be less than 2.5N/mm^2



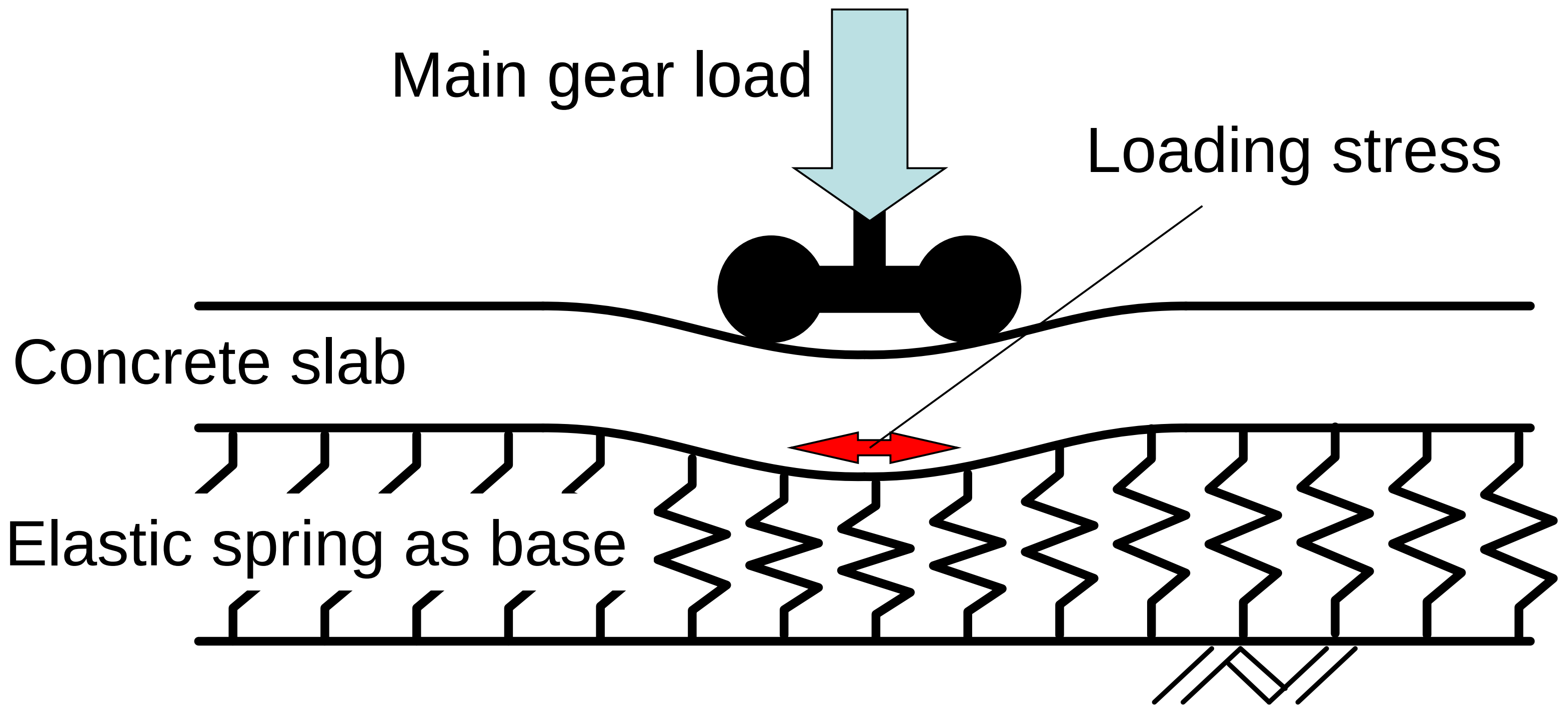
Relationship between slab thickness and σ due to B747-400 landing gear in case K=70MN/m^3

Safety factor considers “effect of load repetition” and
“thermal stress at the bottom of slab due to daily temperature change”.

Mechanistic-Empirical Design of NC Pavement

Loading stress :

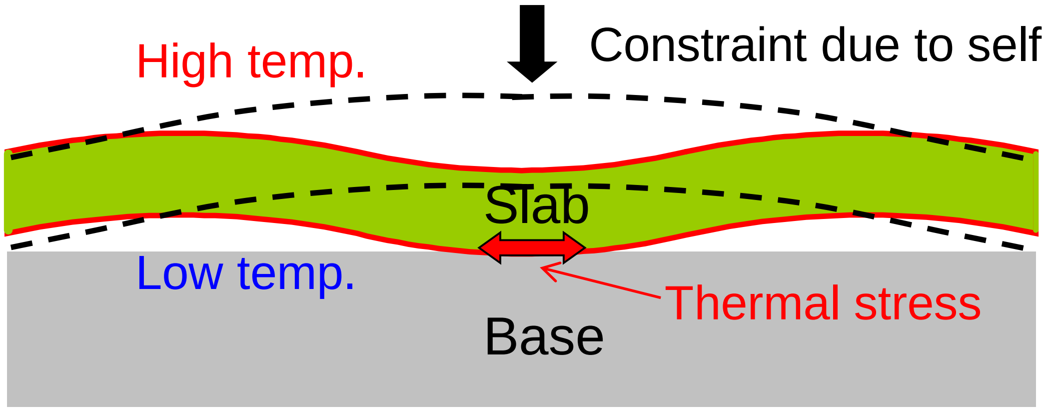
loading stress at center of slab
due to aircraft gear load is calculated by FEM.



Mechanistic-Empirical Design of NC Pavement

Thermal stress :

thermal stress at center of slab is calculated by equation based on long term observation



$$\sigma_t = \beta \frac{E\alpha\theta}{2(1-\nu)}$$

β : -0.772h+0.854

h : slab thickness (m)

E : elastic modulus of concrete (N/mm^2)

α : coefficient of thermal expansion ($1/{}^{o}C$)

θ : temperature difference between top and bottom of slab (${}^{o}C$)

ν : poisson's ratio of concrete

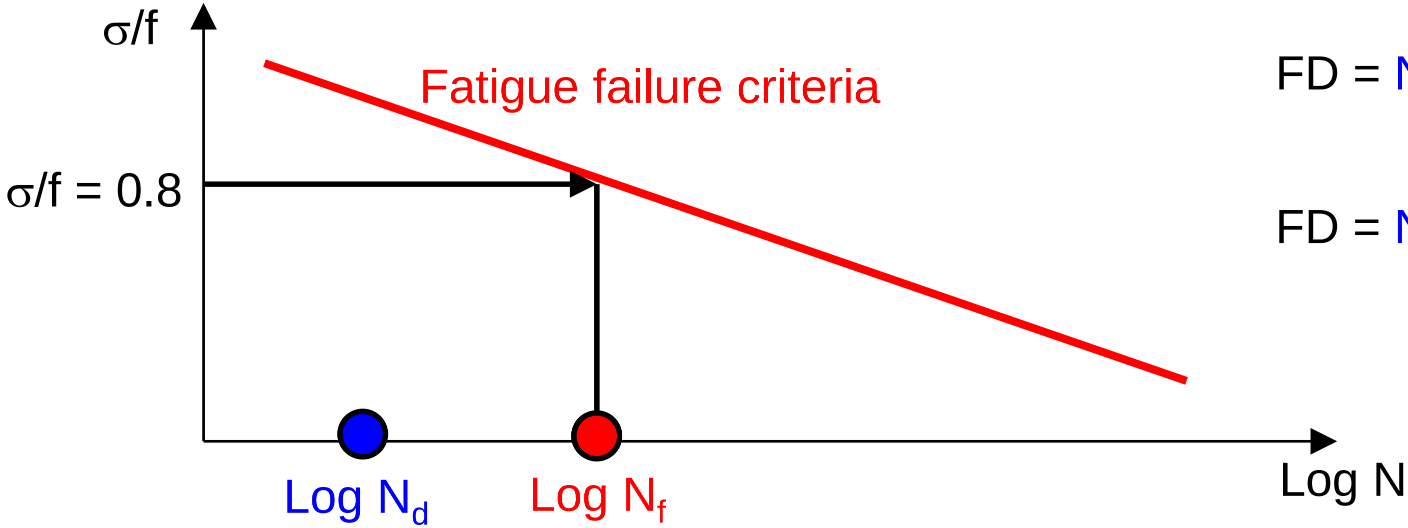
Mechanistic-Empirical Design of NC Pavement

Number of failure :

number of failure is calculated by
total stress and fatigue failure criteria

$$\log N_f = \frac{1.19614 - \sigma / f_{bd,h}}{0.08672}$$

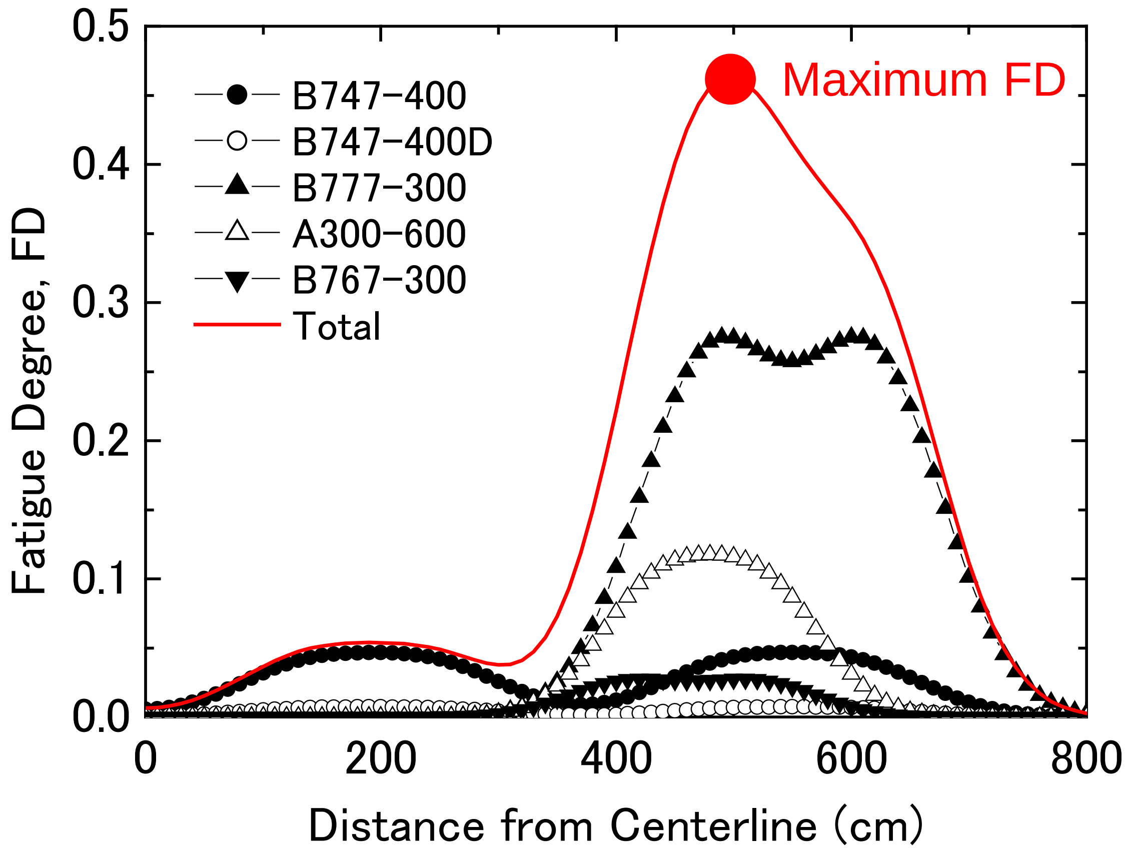
N_f : Number of failure
σ : total stress (=loading stress and thermal stress, N/mm^2)
$f_{bd,h}$: flexural strength with design slab thickness h (N/mm^2)



FD = Nd / Nf < 1.0
-> OK

FD = Nd / Nf > 1.0
-> Redesign

Mechanistic-Empirical Design of NC Pavement



Fatigue degree have to be calculated in transverse direction because gear location and lateral deviation of each aircraft is different.

Construction of Concrete Pavement

Materials

Cement :

Portland cement

Blast-furnace slag cement are used usually.

Aggregate :

Maximum aggregate size : 40mm

Sieve size (mm)	(%)
53	100
37.5	95-100
19	50-100
2.36	20-60
0.075	0-15

Mix Design

Standard of mixture

Design flexural strength : 5.0 N/mm^2 (28 day)

Slump : 2.5 ± 1 cm

Air : 4.5 ± 1.5 %

W/C : less than 50% (generally about 40%)

Cement per unit volume

C = 300-350kg/m^3 is better.

C<300 kg/m^3 -> Bloom finishing may be difficult.

C>350 kg/m^3 -> Initial crack may occur.

Water per unit volume

W =130-140kg/m^3 is better.

W<120 kg/m^3 -> Const. may be difficult in summer.

Mix Design

Flexural strength test (test piece size : 15x15x53 cm)

1. Average strength in 3 test pieces shall be grater than design strength.
2. Each strength shall be grater than 0.85*design strength.

Coefficient of Variation	10%	12.5%	15 %
Overdesign Factor	1.21	1.36	1.55
Target Strength when Design Strength is 5N/mm^2	6.05N/mm^2	6.80N/mm^2	7.75N/mm^2

Construction

Quality control item for subgrade

water content	optimum value
	1time / 1day
degree of compaction	98%
	1time / 2000m^2
Plate loading test	design K_{75}
	1time / 2000m^2

Quality control item for concrete

Slump Air Temperature Flexural strength	1time / 1 day or 150m^3

Construction

Transfer from concrete plant (in case of slump < 2.5cm)

Dump truck should be used.

Paving should be started within 1 hour.

Vibrator

Inner vibrator shall be used in case slab thickness is larger than 30cm.

Mesh steel

Mesh steel is inserted at (slab thickness/4+2)cm depth from surface of slab.

Curing

Initial curing : membrane curing

After curing : mat curing

Curing term : 70% of target flexural strength

Slip Form Paving

"Slip form paver" does not require any steel set forms.

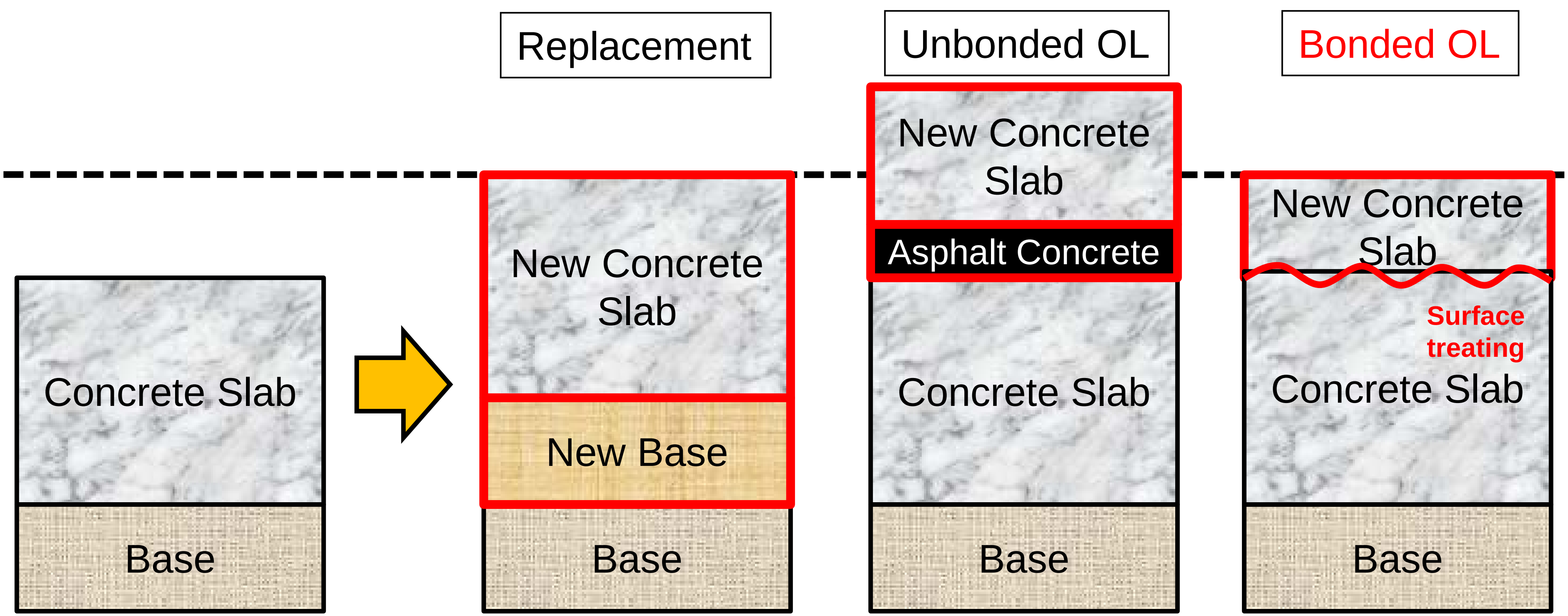
Merit : large construction area per day

Demerit : need to pay attention to concrete mixture specification (slump, air).

No steel form

Concrete Bonded Overlay

Thin concrete layer is constructed on existing slab in case
existing slab is sound and
slope and height have to be modified.



Concrete Bonded Overlay

Bonded strength between new and old layer

1.6 N/mm^2 tensile strength is needed.

Surface treating

1. Water Jet + Shot Blast
2. Shot Blast + Glue Soaking
3. Other ? (1.6 N/mm^2 tensile is needed)

Concrete mixture of new layer

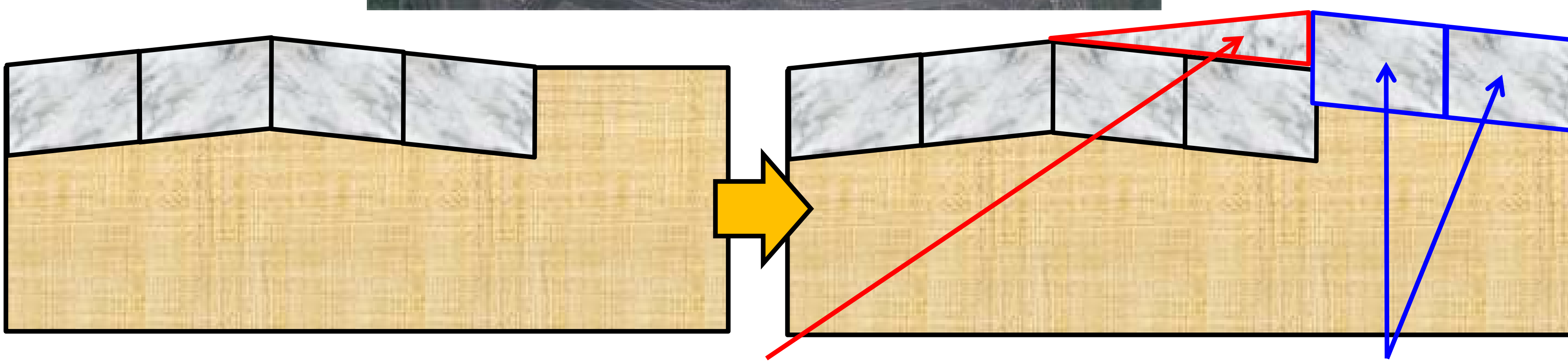
Usual concrete mixture for airport concrete pavement except for maximum aggregate size (40mm -> 20mm)

Overlay thickness

Minimum 5cm

Concrete Bonded Overlay

Example of concrete bonded overlay in New Chitose Airport.

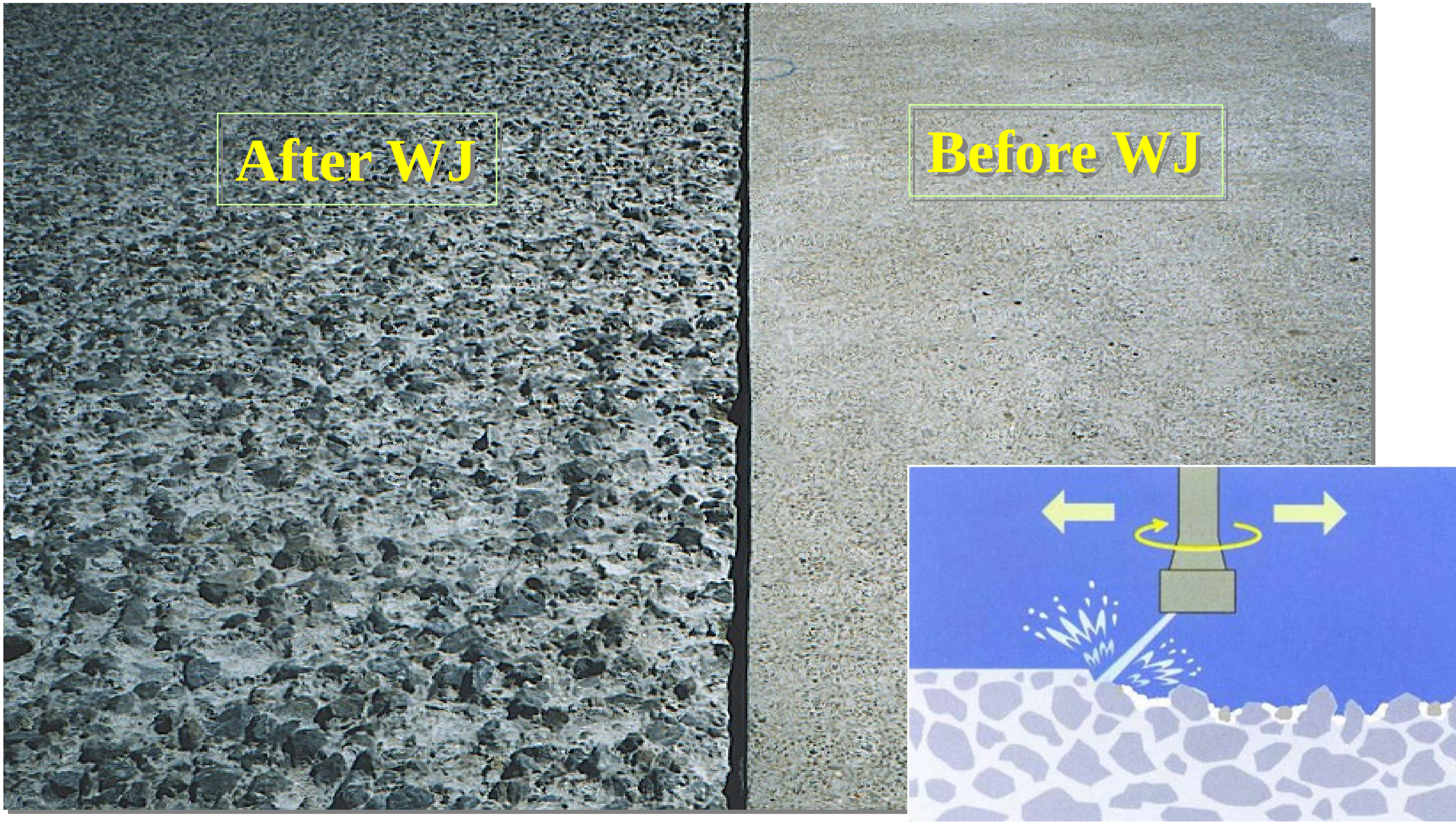


Slope modification
by concrete bonded overlay

New Concrete Slab

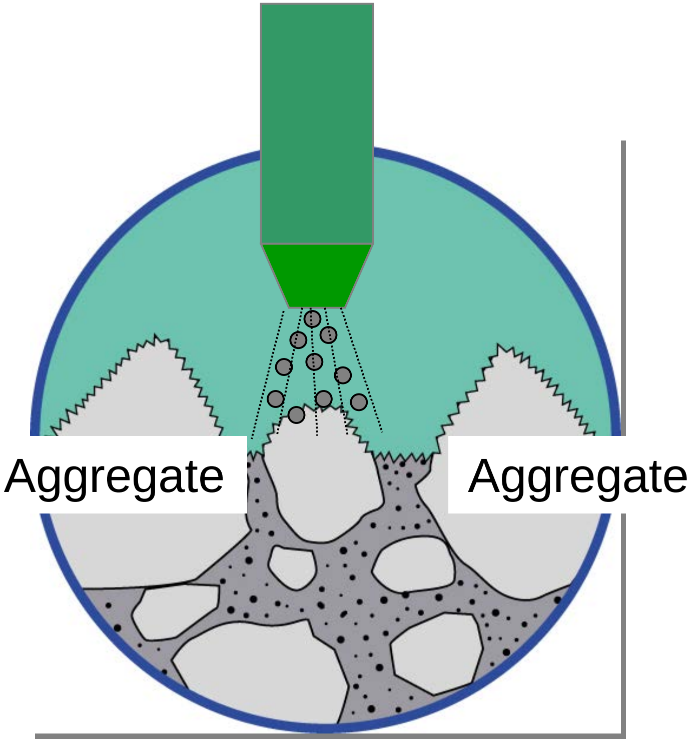
Concrete Bonded Overlay

Surface treating by Water Jet (WJ)



Concrete Bonded Overlay

Surface treating by Shot Blast (SB)



Concrete Bonded Overlay

Surface treating by Shot Blast + Glue Soaking

Shot Blast

Glue Soaking