1993年AASHTO加鋪厚度設計

參考資料：

1. AASHTO, "AASHTO Guide for Design of Pavement Structures," Volume I, 1993. (Chapter 5)
2. **補充講義**(G.1, G.2)

◎ Overlay design analysis

1993 **年** AASHTO Guide **各類加鋪組合之加鋪厚度計算公式如下表所示：**

表一 加鋪厚度計算公式

加鋪材料	現存鋪面	加鋪設計公式
AC	AC	*hol= SNol /a* *=(Snf - SNeff)/a*
AC	Break/PCC	*hol= SNol /a* *=(Snf - SNeff)/a*
AC	PCC	*Dol=A(Df -Deff)*
AC	AC/PCC	*Dol=A(Df -Deff)*
Bonded PCC	PCC	*Dol= Df-Deff*
Unbonded PCC	PCC	$D^2ol= D^2f-D^2eff$
PCC	AC	*Dol= Df*

1993 AASHTO Overlay Design

◎Overlay Type Feasibility

◎Important Considerations in Overlay Design

◎Pavement Evaluation for Overlay Design

※Design of Overlay Along Project

※Functional Evaluation of Existing Pavement

※Structural Evaluation of Existing Pavement

(Figure 5.1)

SC_0, SC_f

SC_{eff} (=SN_{eff} for AC, or D_{eff} for PCC and Composite Pavements)

$SC_{OL} = SC_f - SC_{eff}$

1. Visual Survey & Material Testing
2. NDT
3. Remaining Life (Figure 5.2)

$$RL = 100\left(1 - \frac{N_p}{N_{1.5}}\right)$$

$$CF = \frac{SC_n}{SC_0}$$

$$SN_{eff} = CF(SN_0)$$

Note: N_p, $N_{1.5}$ for traffic or ESAL

※Determination of Design M_R (Figure 5.4)

1. Lab. Testing
2. NDT Backcalculation
3. Estimate from Correlation Studies
4. Original Design & Construction Data

$$Design\ M_R = C\left(\frac{0.24\ P}{d_r r}\right)$$

$$C \le 0.33$$

Note: r = sufficient large distance from the loading plate

◎AC Overlay of AC Pavement

$$SN_{OL} = a_{OL}(D_{OL}) = SN_f - SN_{eff}$$

Step 1: Existing Pavement Design & Construction

Step 2: Traffic Analysis

Step 3: Condition Survey

Step 4: Deflection Testing (Strongly Recommended)

1. Subgrade Resilient Modulus (M_R)

$$M_R = \left(\frac{0.24\ P}{d_r r}\right)$$

其中 M_R **為路床回彈模數值**(psi)**，**P **為施加荷重**(lbs**；規範建議使用** $9000\ lb$)**，**d_r **為離荷重中心距離所量得之撓度值**(in)**，**r **為離荷重中心距離**(in)**，距離** r **的選取則建議** $r \ge 0.7a_e$**，求取公式如下。**

(d_r must be measured far enough away to provide a good estimate of subgrade modulus, independent of the effects of any layers above, but also close enough that is not too small to measure accurately)

$$a_e = \sqrt{\left[a^2 + \left(D * \sqrt[3]{\left(E_p / M_R \right)} \right)^2 \right]}$$

公式中 a_e **為路床與鋪面之間應力分佈半徑**(*in*；*stress bulb*)，a **為荷重盤半徑**(*in*；**建議取** *5.9 in*)，D **為鋪面各層總厚度**(*in*)，E_p **為路床以上鋪面有效回彈模數值**(*psi*)，M_R **為路床回彈模數值**(*psi*)。

2. Temperature of AC Mix
3. Effective Modulus of the Pavcement (E_p)

$$d_0 = 1.5pa \left[\frac{1}{M_R \sqrt{1 + \left(\frac{D}{a} * \sqrt[3]{\left(E_p / M_R \right)} \right)^2}} + \frac{1 - \frac{1}{\sqrt{1 + (D/a)^2}}}{E_p} \right]$$

由 Figure 5.5 ㅒ E_p / M_R ㅒ **求** E_p = ?

d_0 = adjusted to a standard temperature 68 ^oF (Figure 5.6 - Figure 5.7)

Step 5: Coring and Material Testing (Strongly Recommended)

M_R=1500CBR (may be too high)

Step 6: Determine the Required Structural Number (SN_f)for Future Traffic

$$Design\ M_R = C\left(\frac{0.24\,P}{d_r r}\right)$$

$C \le 0.33$

冄求 SN_f (Using AASHTO Design Equation)

Step 7: Determine SN_{eff}

1. SN_{eff} from NDT for AC Pavements

$$SN_{eff} = 0.0045D\sqrt[3]{E_p}$$

(Figure 5.8)

2. SN_{eff} from Condition Survey

$$\mathrm{SN_{eff}} = a_1 D_1 + a_2 D_2 m_2 + a_3 D_3 m_3$$

(Table 5.2)

e.g., a_1 = 0.34 (good), 0.25 (fair), 0.15(poor)

3. SN_{eff} from Remaining Life

$$RL = 100\left(1 - \frac{N_p}{N_{1.5}}\right)$$

$$SN_{eff} = CF(SN_0)$$

Step 8: Determine Overlay Thickness (D_{OL})

$$D_{OL} = SN_{OL} / a_{OL} = (SN_f - SN_{eff}) / a_{OL}$$

◎AC Overlay of Fractured PCC Slab Pavement

$$SN_{OL} = a_{OL}(D_{OL}) = SN_f - SN_{eff}$$

Step 1 ~ Step 5: Same as Before

Step 6: Determine SN_f

$$Design\ M_R = C\left(\frac{0.24P}{d_r r}\right)$$

$$C = 0.25\ or\ less$$

卄求 SN_f (Using AASHTO Design Equation)

(Design ΔPSI, Overlay Design Reliability R, Overlay Standard Deviation S_0)

Step 7: Determine SN_{eff} (from Condition Survey)

$$SN_{eff} = a_2 D_2 m_2 + a_3 D_3 m_3$$

Step 8: Same as Before

◎AC Overlay of JPCP, JRCP, and CRCP Pavement

$$D_{OL} = A(D_f - D_{eff})$$

$$A = 2.2233 - 0.1534(D_f - D_{eff}) + 0.0099(D_f - D_{eff})^2$$

A= Factor to convert PCC thickness deficiency to AC overlay thickness

Step 1 ~ Step 3: Same as Before

Step 4: Deflection Testing (Strongly Recommended)

FWD, AREA

$$AREA = 6\left(1 + 2\frac{d_{12}}{d_0} + 2\frac{d_{24}}{d_0} + \frac{d_{36}}{d_0}\right)$$

1. Effective Dynamic k-value (k_{dyn})

   由 d_0, AREA ==> Find k_{dyn} = ? (查圖)

   (K. T. Hall's Closed-Form Solution)

2. Effective Static k-value (k_{stat})

   $k_{stat} = k_{dyn} / 2$

3. Elastic Modulus of PCC Slab (E)

   由 AREA, k_{dyn} ==> ED^3 ==> Find E = ?

   (Typical E = 3 ~ 8 Mpsi)

4. Joint Load Transfer for JPCP/JRCP

$$\Delta LT = 100\left(\frac{\Delta_{UL}}{\Delta_L}\right)B$$

$$B = \frac{d_{0\,center}}{d_{12\,center}}$$

   B= Slab Bending Correction Factor

   (Typical B = 1.05 ~ 1.15)

   (Don't measure it if air temperature ≥ 80^{o}F)

   a. Determine JPCP/JRCP Load Transfer Coefficient (J), J = 3.2 ~ 3.5 ~ 4.0 (%LT>70 ~ 50<%LT<70 ~ %LT<50)

   b. For CRCP, use J = 2.2 ~ 2.6 for Overlay Design

Step 5: Coring and Material Testing (Strongly Recommended)

PCC Modulus of Rupture, S_c'

$$S_c' = 210 + 1.02IT \quad \text{(psi)}$$

IT= indirect tensile strength of 6" diameter cores, psi

Step 6: Determine D_f

1. Effective Static k-value (k_{stat})
   a. $k_{stat} = k_{dyn} / 2$ (k_{dyn} from Backcalculation)
   b. Conduct plate load test
   c. Estimate from soils data and base type and thickness from charts
2. Design ΔPSI
3. J Load Transfer Coefficient
4. PCC Modulus of Rupture

$$S_c' = 210 + 1.02/T \quad \text{(psi)}$$

$$S_c' = 43.5\left(\frac{E}{10^6}\right) + 488.5 \quad \text{(psi)}$$

   E = Backcalculated E_{pcc}
5. E_{pcc}
6. Loss of Support of Existing Slab
   For OL design, assume fully supported LS=0
7. R, S_o, C_d(drainage)

(Using AASHTO Design Equation)

Step 7: Determine D_{eff}

1. D_{eff} from Visual Survey

$$D_{eff} = F_{jc}(F_{dur})(F_{fat})D$$

F_{jc} = joints and cracks (0.5 ~ 1.0), if repaired all cracks F_{jc} = 1.0

F_{dur} = durability (0.8 ~ 1.0)

F_{fat} = fatigue damage (0.9 ~ 1.0)

2. D_{eff} from Remaining Life

$$RL = 100\left(1 - \frac{N_p}{N_{1.5}}\right)$$

$$D_{eff} = CF\,(D)$$

(From RL ==> determine CF)

Step 8: Determine Overlay Thickness (D_{OL})

$$D_{OL} = A(D_f - D_{eff})$$

$$A = 2.2233 - 0.1534(D_f - D_{eff}) + 0.0099(D_f - D_{eff})^2$$

◎AC Overlay of AC/JPCP, AC/JRCP, and AC/CRCP

$$D_{OL} = A(D_f - D_{eff})$$

$$A = 2.2233 - 0.1534(D_f - D_{eff}) + 0.0099(D_f - D_{eff})^2$$

Step 1 ~ Step 3: Same as Before

Step 4: Deflection Testing (Strongly Recommended)

1. Temperature of AC Mix
2. Elastic Modulus of AC

$$\log E_{ac} = f(P_{200},\ \mathrm{F},\ \mathrm{V_v},\ \eta_{70^oF,10^6 poise},\ P_{ac},\ t_p)$$

(% passing #200, load frequency Hz, air voids, absolute viscosity, % asphalt, AC mix temperature)

3. Effective Dynamic k-value (k_{dyn}) beneath PCC Slab

a. Compute compression between AC (d_{0comp})

$$d_{0compress} = -0.0000328 + 121.5006\left(\frac{D_{ac}}{E_{ac}}\right)^{1.0798} \quad \text{Bonded}$$

$$d_{0compress} = -0.00002133 + 38.6872\left(\frac{D_{ac}}{E_{ac}}\right)^{0.94551} \quad \text{Unbonded}$$

b. Compute $AREA_{PCC}$

$$AREA_{PCC} = 6\left(1 + 2\frac{d_{12}}{d_{0PCC}} + 2\frac{d_{24}}{d_{0PCC}} + \frac{d_{36}}{d_{0PCC}}\right)$$

d_{0PCC} = PCC deflection in the center of loading plate = d_0 - $d_{0compress}$

d_i = deflection at 12, 24, 36”

c. Backcalculate k_{dyn}

(K. T. Hall's Closed-Form Solution)

4. Effective Static k-value (k_{stat})

$k_{stat} = k_{dyn} / 2$

5. Elastic Modulus of PCC Slab (E)

由 AREA, k_{dyn} ==> ED^3 ==> Find E = ?

6. Joint Load Transfer for JPCP/JRCP

$$\Delta LT = 100\left(\frac{\Delta_{UL}}{\Delta_L}\right)B$$

$$B = \frac{d_{0center}}{d_{12center}}$$

B and J factor: same as before

Step 5: Coring and Material Testing (Strongly Recommended)

1.Modulus of AC Surface

$$\log E_{ac\,t^oF} = \left(\frac{\log E_{ac\,70^oF} - \log E_{ac\,90^oF}}{70-90} \right) *$$
$$(t^oF - 70^oF) + \log E_{ac\,70^oF}$$

2. PCC Modulus of Rupture, S_c'

$$S_c' = 210 + 1.02/T \quad \text{(psi)}$$

Step 6: Determine D_f

1. Determine k_{stat}, ΔPSI, J, S_c', E_{pcc} , LS, R, S_o, C_d

$$S_c' = 210 + 1.02/T \quad \text{(psi)}$$

$$S_c' = 43.5\left(\frac{E}{10^6}\right) + 488.5 \quad \text{(psi)}$$

2. Using AASHTO Design Equation

Step 7: Determine D_{eff}

$$D_{\text{eff}} = D_{PCC}(F_{jc})(F_{dur}) + \frac{D_{ac}}{2.0}(F_{ac})$$

F_{jc} = joints and cracks (0.5 ~ 1.0), if repaired all cracks F_{jc} = 1.0

F_{dur} = durability (0.8 ~ 1.0)

F_{ac} = AC quality adjustment (0.8 ~ 1.0)

Step 8: Determine D_{OL}

$$D_{OL} = A(D_f - D_{eff})$$

$$A = 2.2233 - 0.1534(D_f - D_{eff}) + 0.0099(D_f - D_{eff})^2$$

◎Bonded Concrete Overlay of JPCP, JRCP, and CRCP

$$D_{OL} = D_f - D_{eff}$$

Step 1 ~ Step 2: Same as Before

Step 3: Condition Survey

JPCP/JRCP: Joint Deterioration, Transverse Cracks, Expansion Joints, Durability, Faulting, Pumping

CRCP: Punchouts, Deteriorated Transverse Cracks

Step 4: Deflection Testing (Strongly Recommended)

1. AREA (same definition)
2. Effective Dynamic k-value (k_{dyn}) from Backcalculation

(K. T. Hall's Closed-Form Solution)

3. Effective Static k-value, $k_{stat} = k_{dyn} / 2$
4. Elastic Modulus of PCC Slab (E)

由 AREA, k_{dyn} ==> ED^3 ==> Find E = ?

6. Joint Load Transfer for JPCP/JRCP

$$\Delta LT = 100\left(\frac{\Delta_{UL}}{\Delta_L}\right)B$$

$$B = \frac{d_{0\,center}}{d_{12\,center}}$$

B and J factor: same as before

Step 5: Coring and Material Testing (Strongly Recommended)

$$S_c' = 210 + 1.02\,IT \quad \text{(psi)}$$

Step 6: Determine D_f

Using AASHTO Design Equation (Same as before)

Step 7: Determine D_{eff}

1. Visual Survey

$$D_{\text{eff}} = (F_{jc})(F_{dur})(F_{fat})D$$

2. Remaining Life

$$RL = 100\left(1 - \frac{N_p}{N_{1.5}}\right)$$

$$D_{eff} = CF(D)$$

Step 8: Determine D_{OL}

$$D_{OL} = D_f - D_{eff}$$

◎Unbonded JPCP, JRCP & CRCP Overlay of JPCP, JRCP, CRCP, and AC/PCC

$$D_{OL} = \sqrt{D_f^{\,2} - D_{eff}^{\,2}}$$

Step 1 ~ Step 3: Same as Before

Step 4: Deflection Testing (Strongly Recommended)

1. AREA (same definition)
2. Effective Dynamic k-value (k_{dyn}) from Backcalculation
   (K. T. Hall's Closed-Form Solution)
3. Effective Static k-value, $k_{stat} = k_{dyn} / 2$

Step 5: Coring and Material Testing (Not Needed)

Step 6: Determine D_f

Using AASHTO Equation (Same as before)

Step 7: Determine D_{eff}

1. Visual Condition Survey

$$D_{eff} = (F_{jcu}) D$$

F_{jcu} = joints and cracks adjustment factor for unbonded PCC (0.95 ~ 1.0)

Note:

a. existing AC in neglected

b. F_{dur} and F_{fat} are not used for unbonded PCC overlay

c. F_{jcu} factor is modified and reduced

2. Remaining Life

$$RL = 100\left(1 - \frac{N_p}{N_{1.5}}\right)$$

$$D_{eff} = CF(D)$$

Step 8: Determine D_{OL}

$$D_{OL} = \sqrt{D_f^{\,2} - D_{eff}^{\,2}}$$

◎ JPCP, JRCP & CRCP Overlay of AC Pavement

$D_{OL} = D_f$

Step 1 ~ Step 3: Same as Before

Step 4: Deflection Testing (Strongly Recommended)

1. Subgrage Resilient Modulus, M_R (same as before)
2. Effective Dynamic k-value (k_{dyn}) from Backcalculation

Use M_R, E_P, D (total thickness above subgrade), and Figure 3.3 (Page II-39) → Find K_{dyn} = ?
(Don't need C=0.33 here!!!)

Step 5: Coring and Material Testing (<u>Usually Not Needed</u>)

Step 6: Determine D_f

Using AASHTO Equation (Same as before)

Step 7: Determine D_{OL}

$D_{OL} = D_f$

Homework:

Use the Pavement Analysis Software (PAS) to conduct new pavement design and overlay design