ENCE 717
BRIDGE ENGINEERING
ABUTMENT/PIER DESIGN
(Ref: FHWA PSC Girder Design)

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Integral Abutment Design (1)

Pile Cap (7.1.2)

- **Stage I (noncomposite)**
  
  \[ P_{SI} = 1.25 \times (\text{girder} + \text{slab} + \text{haunch}) \]

- **Final Stage (composite)**
  
  \[ P_{FNL} = 1.25(\text{DC}) + 1.50(\text{DW}) + 1.75(\text{LL} + \text{IM}) \frac{N_{\text{lanes}}}{N_{\text{girders}}} \]

Pile (7.1.3)

- **Case A** – Capacity of the pile
- **Case B** – Transfer load to the ground
- **Case C** – Ground to support the load
  
  (assume rock, only Case A needs to be investigated.)

Figure 7.1-1 – General View of an Integral Abutment Showing Dimensions Used for the Example
Backwall (7.1.4) (80% of)

- **Case A** -
  \[ P_u = 1.5 \times (\text{girder} + \text{slab}) \]
  \[ w_u = 1.5 \times (\text{pile cap} + \text{diaphragm}) \]

- **Case B** -
  \[ P_{Str-I} = \text{factored girder reaction} \]
  \[ w_{Str-I} = 1.25(\text{pile cap} + \text{end diaph.} + \text{approach slab}) + 1.50(\text{approach FWS}) + 1.75(\text{approach slab lane load}) \left( \frac{N_{lanes}}{N_{girders}} \right) \]
Figure 7.1-5 – Integral Abutment Reinforcement, No Girder and No Pile at the Section

Figure 7.1-4 – Integral Abutment Reinforcement, Girder and Pile Exist at the Same Section
Figure 7.1-6 – Integral Abutment Reinforcement, Girder, No Pile at the Section

Figure 7.1-7 – Integral Abutment Reinforcement, Pile Without Girder
Integral Abutment Design (3)

Backwall (7.1.4)
- Passive pressure -
  \[ w_p = \frac{1}{2} \times \gamma z^2 k_p \]
  \[ w_u = 1.5 \times w_p \]

Design the backwall as a horizontal beam resisting passive earth pressure.

Figure 7.1-8 – Passive Earth Pressure Applied to Backwall
Integral Abutment Design (4)

Wingwall (7.1.5)

- **Passive pressure** \((k_p=3)\) -
  
  \[ w_u \text{ at bottom of slab}=0.2\text{k/ft}^2; \text{ at boi} \]

  \[ M_p = (\text{Rect. Volume} \times \frac{1}{2} \text{ base length}) + (\text{pyramid volume} \times \frac{1}{4} \text{ base length}) \]

- **Active pressure** \((k_a = 0.333)\) –
  
  \[ M_a = (k_a/k_p)M_p + M_{\text{collision}} \]
Integral Abutment Design (5)

Approach Slab (7.1.6)

- **Single lane loaded**
  \[ E = 10 + 5 \sqrt{L_1 W_1} \]

- **Multiple lane loaded**
  \[ E = 84 + 1.44 \sqrt{L_1 W} \leq 12W/N_L \]

\[ M_u = w^2/8 + 1.75 \ (LL+IM \ Moment) \]
Intermediate Pier Design (1)

Girders (E/I) = 61.6 k
Deck slab and haunch (E) = 55.1 k
Deck slab and haunch (I) = 62.2 k
Intermediate diaphragm (E) = 1.3 k
Intermediate diaphragm (I) = 2.5 k
Parapets (E/I) = 14.8 k
Future wearing surface (E) = 13.4 k
Future wearing surface (I) = 19.9 k

Figure 7.2-1 – General Pier Dimensions
Intermediate Pier Design (2)

Girders (E/I) = 61.6 k
Deck slab and haunch (E) = 55.1 k
Deck slab and haunch (I) = 62.2 k
Intermediate diaphragm (E) = 1.3 k
Intermediate diaphragm (I) = 2.5 k
Parapets (E/I) = 14.8 k
Future wearing surface (E) = 13.4 k
Future wearing surface (I) = 19.9 k

Figure 7.2-2 – Super- and Substructure Applied Dead Loads
Intermediate Pier Design (3)

- **Longitudinal** –
  - Braking force (BR)
  - Wind load along axes of superstructure
  - Wind load on sub = $W_{\text{cap}} + W_{\text{col}}$

- **Transverse** –
  - Wind load transverse to the superstructure
  - Wind load on sub
  - Wind on live load

*Figure 7.2-3 – Wind and Braking Loads on Super- and Substructure*
Intermediate Pier Design (4)

- **Moment** –
  \[ \sigma_1, \sigma_2 = \frac{P}{LW} \pm M_c \left( \frac{L}{2} \right) \left( \frac{L^3 W}{12} \right) \]
  \[ \sigma_5, \sigma_6 = \frac{P}{LW} \pm M_c \left( \frac{L}{2} \right) \left( \frac{W^3 L}{12} \right) \]

- **Shear** –
  \[ V_{ux} = \sigma_4 L_2 + 0.5(\sigma_1 - \sigma_4)L_2 \]
  \[ V_{uy} = \sigma_8 L_4 + 0.5(\sigma_5 - \sigma_8)L_4 \]
  \[ \text{Two-way (punching shear)} \]

*Figure 7.2-11 – Stress at Critical Locations for Moment and Shear*