Integral Abutment

Integral abutments are used to eliminate expansion joints at the end of a bridge. They often result in “Jointless Bridges” and serve to accomplish the following desirable objectives:

- Long-term serviceability of the structure
- Minimal maintenance requirements
- Economical construction
- Improved aesthetics and safety considerations

Integral Abutment Design (1)

Pile Cap (7.1.2)
- Stage I (noncomposite)
  \[ P_{nj} = 1.25 \times (\text{girder} + \text{slab} + \text{haunch}) \]
- Final Stage (composite)
  \[ P_{FNL} = 1.25(DC) + 1.50(DW) + 1.75(LL + IM) \times \left( \frac{N_{lanes}}{N_{girders}} \right) \]

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.)

Integral Abutment Design (2)

Backwall (7.1.4) (80% of simple beam moment)
- Case A -
  \[ P_{u} = 1.5 \times (\text{girder} + \text{slab}) \]
  \[ w_{uj} = 1.5 \times (\text{pile cap} + \text{diaphragm}) \]
- Case B -
  \[ P_{Str-I} = \text{factored girder reaction} \]
  \[ w_{Str-I} = 1.25(pile cap + end diaph. + approach slab) + 1.50 \times (\text{approach FWS}) + 1.75(\text{approach slab lane load}) \times \left( \frac{N_{lanes}}{N_{girders}} \right) \]

Assume abutment beam as a simple span
Pile Design

Generally, the design of the piles is controlled by the minimum capacity as determined for the following cases:

- **Case A** - Capacity of the pile as a structural member. The design for combined moment and axial force will be based on an analysis that takes the effect of the soil into account.
- **Case B** - Capacity of the pile to transfer load to the ground.
- **Case C** - Capacity of the ground to support the load.

For piles on competent rock, only Case A needs to be investigated.

Integral Abutment Design (3)

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

**Backwall (7.1.4)**

- Passive pressure -
  
  \[ W_p = \frac{1}{2} \gamma z^2 k_p \]
  
  \[ W_u = 1.5 \times W_p \]

Figure 7.1.8 – Passive Earth Pressure Applied to Backwall
Wingwall (7.1.5)
- Passive pressure ($k_p = 3$) -
  \[ w_u \text{ at bottom of slab} = 0.2 \text{k/ft}^2; \text{ at bottom of wall} = 3.24 \text{k/ft}^2 \]
  \[ M_p = (\text{Rect. Volume} \times \frac{1}{2} \text{ base length}) + (\text{pyramid volume} \times \frac{1}{4} \text{ base length}) \]
- Active pressure ($k_a = 0.333$) -
  \[ M_a = (k_a/k_p)M_p + M_{\text{collision}} \]

Active pressure formula:
\[ M_a = (k_a/k_p)M_p + M_{\text{collision}} \]

Intermediate Pier Design (1)
- Girders (E/I) = 61.6 k
- Deck slab and hunch (E) = 55.1 k
- Deck slab and hunch (f) = 62.2 k
- Intermediate diaphragm (E) = 1.3 k
- Intermediate diaphragm (f) = 2.5 k
- Parapets (E/I) = 14.8 k
- Future wearing surface (E) = 13.4 k
- Future wearing surface (f) = 19.9 k

Intermediate Pier Design (2)
- Girders (E/I) = 61.6 k
- Deck slab and hunch (E) = 55.1 k
- Deck slab and hunch (f) = 62.2 k
- Intermediate diaphragm (E) = 1.3 k
- Intermediate diaphragm (f) = 2.5 k
- Parapets (E/I) = 14.8 k
- Future wearing surface (E) = 13.4 k
- Future wearing surface (f) = 19.9 k

Single lane loaded
\[ E = 10 + 5 \sqrt{(L_1W_1)} \]

Multiple lane loaded
\[ E = 84 + 1.44 \sqrt{(L_1W)} \leq 12W/N_L \]
\[ M_u = wP/8 + 1.75 \times (\text{LL+IM Moment}) \]
Live Load Consideration

- First, one lane is loaded. The reaction from that lane is moved across the width of the bridge. To maximize the loads, the location of the 12 ft wide traffic lane is assumed to move across the full width of the bridge between gutter lines. For each load location, the girder reactions transmitted to the pier are calculated and the pier itself is analyzed.

- Second, two traffic lanes are loaded. Each of the two lanes is moved across the width of the bridge to maximize the load effects on the pier. All possible combinations of the traffic lane locations should be included.

- The calculations are repeated for three lanes loaded, four lanes loaded and so forth depending on the width of the bridge.

Live Load Consideration (cont.)

- The maximum and minimum load effects, i.e. moment, shear, torsion and axial force, at each section from all load cases are determined as well as the other concurrent load effects, e.g. maximum moment and concurrent shear and axial loads.

- When a design provision involves the combined effect of more than one load effect, e.g. moment and axial load, the maximum and minimum values of each load effect and the concurrent values of the other load effects are considered as separate load cases. This results in a large number of load cases to be checked.

- Alternatively, a more conservative procedure that results in a smaller number of load cases may be used. In this procedure, the envelopes of the load effects are determined. For all members except for the columns and footings, the maximum values of all load effects are applied simultaneously.

- For columns and footings, two cases are checked, the case of maximum axial load and minimum moment and the case of maximum moment and minimum axial load.

Intermediate Pier Design (3)

- **Transverse**
  - Wind load transverse to the superstructure
  - Wind load on sub
  
  \[
  F_{\text{F, Super}} = P_{\text{W, Wind}} \times \frac{L_{\text{back}} + L_{\text{ahead}}}{2}
  \]
  - Wind on live load

- **Longitudinal**
  - Braking force (BR)
  - Wind load along axes of superstructure
  
  \[
  F_{\text{L, Super}} = P_{\text{W, Wind}} \times \frac{L_{\text{back}} + L_{\text{ahead}}}{n \text{ fix piers}}
  \]
  - Wind load on sub

Intermediate Pier Design (4)

- **Moment**
  - \(\sigma_1, \sigma_2 = \frac{P}{LW} \pm \frac{M}{L(2)(L^3W/12)}\)
  - \(\sigma_5, \sigma_6 = \frac{P}{LW} \pm \frac{M}{L(2)(W^3L/12)}\)

- **Shear**
  - \(V_{ux} = \sigma_4 L_2 + 0.5(\sigma_1 - \sigma_4)L_2\)
  - \(V_{uy} = \sigma_3 L_4 + 0.5(\sigma_5 - \sigma_3)L_4\)
  - Two-way (punching shear)