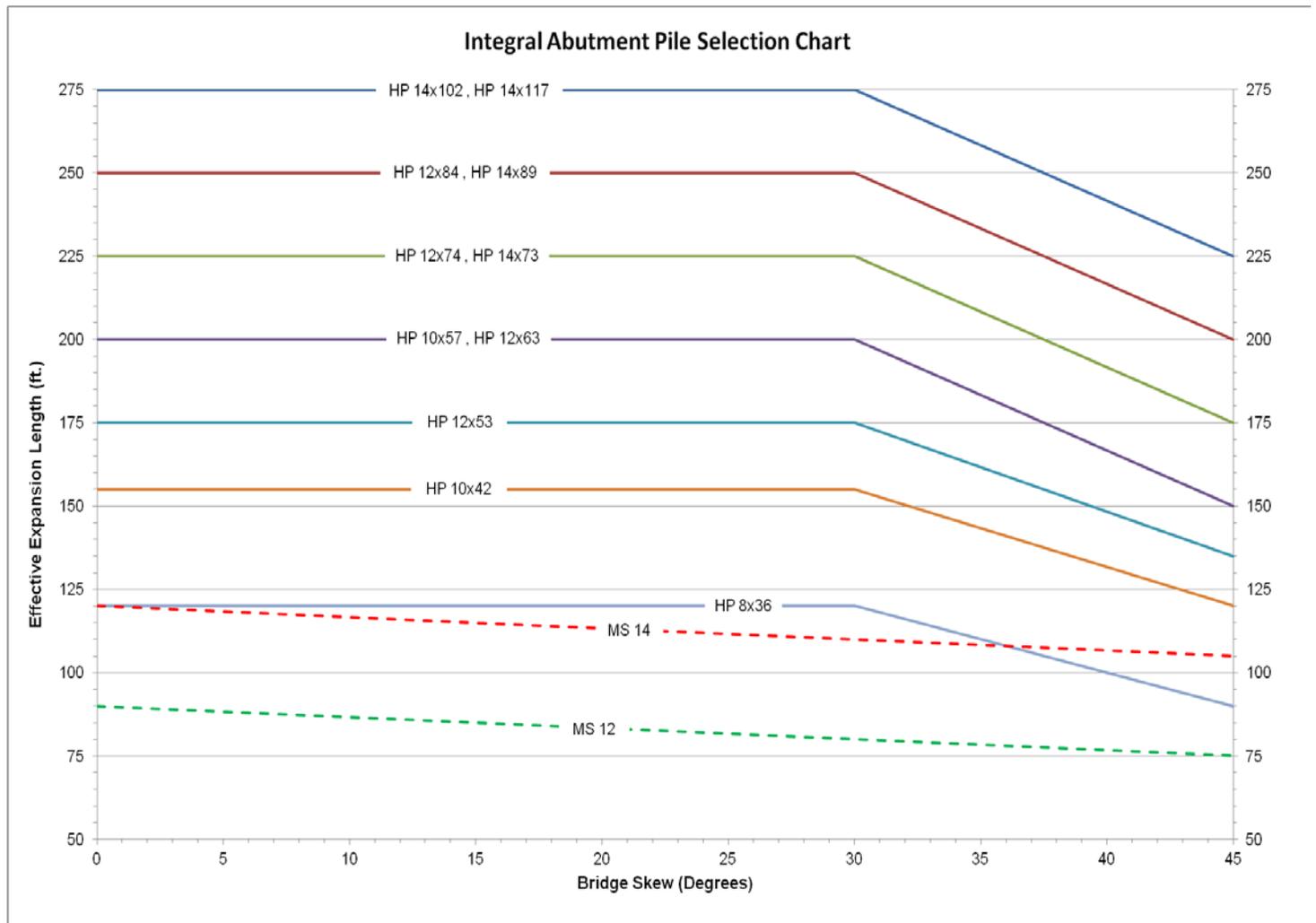


Integral Abutment Pile Selection

Integral abutment bridges eliminate the need for joints in bridge decks and thereby provide better protection from water and salt damage to the superstructure. The Department has always strived to increase the number of structures eligible for integral design but recognized that a site's soil strength and final pile type/size selected play as much of a role in this decision as do structure length and skew. Recent research and analysis has resulted in IDOT issuing the following procedure and a corresponding spreadsheet allowing planners a simple way to quickly determine if the use of integral abutments is possible as well as designers a way to select a pile size which will not be overstressed in combined bending. An extensive parametric study of bridge length, skew, soil type/strength and pile type/size was conducted and resulted in the following Integral Abutment Pile Selection Chart.



The chart is used by plotting the point where the controlling Effective Expansion Length (EEL) and structure skew meet. Any piles indicated on lines at or above this point may be used to support the integral abutment. These piles have been sized to carry both the moment due to thermal expansion and their maximum factored loading, satisfying all AASHTO LRFD design requirements.

The EEL is typically half the bridge length but may need to be increased based on soil strength or unequal number of piles at each abutment. The chart assumes the abutment piles will be driven into cohesive soils with an unconfined compressive strength (Q_u) of 1.5 tsf. The soil borings at each abutment must be checked to determine if the average Q_u within the first 10 ft. below the bottom of each abutment exceeds 1.5 tsf. If any new embankment is required below the proposed abutment, those layers shall be assumed to have a Q_u of 1.25 tsf. If any granular soil layers exists within this 10 ft. depth, it must be included in the average by converted it to an equivalent cohesive soil Q_u using the following formula:

$$Q_u = 0.75\ln(N) + 0.7$$

where:

N = Standard Penetration Test (SPT) blow count

If the average Q_u at one or both abutment is exceeds 1.5 tsf and is less than 3.0 tsf., the following pile stiffness modifier (M) must be used to account for the increased pile stress due to the higher soil strength.

$$M_{east} = \frac{1}{1.45 - 0.3Q_{u_{east}}} \geq 1.0$$

The distance to the centroid of stiffness from each abutment is determined using the pile stiffness modifier at each abutment and an estimate of the number of piles at each abutment as shown below:

$$\Sigma_{Stiff. West Abut.} = \frac{(\text{num. of west abut. piles})(0)(M_{west}) + (\text{num. of east abut. piles})(M_{east})(\text{bridge length})}{(\text{num. of west abut. piles})(M_{west}) + (\text{num. of east abut. piles})(M_{east})}$$

$$\Sigma_{Stiff. East Abut.} = \Sigma_{Stiff. West Abut.} - \text{bridge length}$$

The larger centroid of stiffness is the controlling expansion length. If the Q_u at this abutment is > 1.5 tsf., this controlling expansion length must be increased by the “ Q_u correction factor” which is the ratio of the average Q_u at the abutment over 1.5 tsf.

$$EEL = (\text{controlling expansion length}) \times (Q_{u_{ave. at abut}}) / 1.5$$

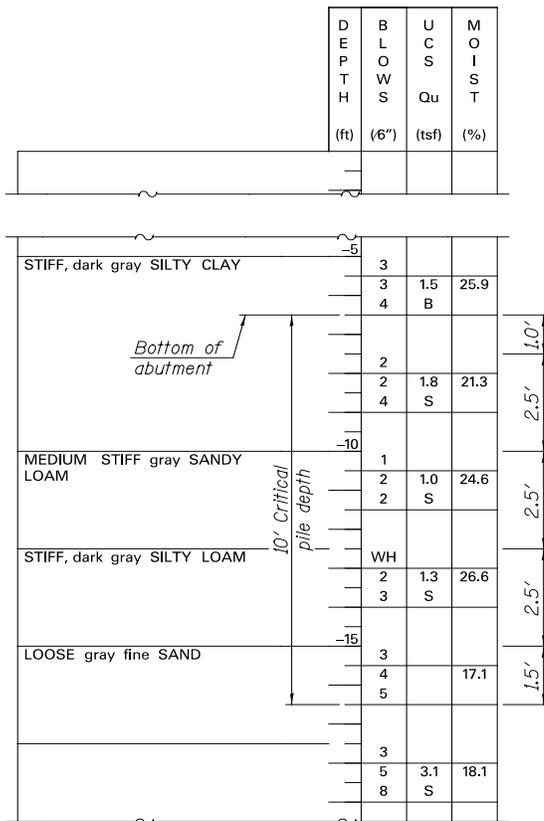
If the EEL exceeds the highest available pile line in the chart, then an integral abutment is not feasible. In these cases, a joint in the structure may still be avoided by utilizing a semi-integral abutment structure. Semi-Integral abutments may be used with structures whose total structure length does not exceed 550 feet and whose skew is ≤ 45 degrees.

The following are a few limitations that must be considered when using the chart:

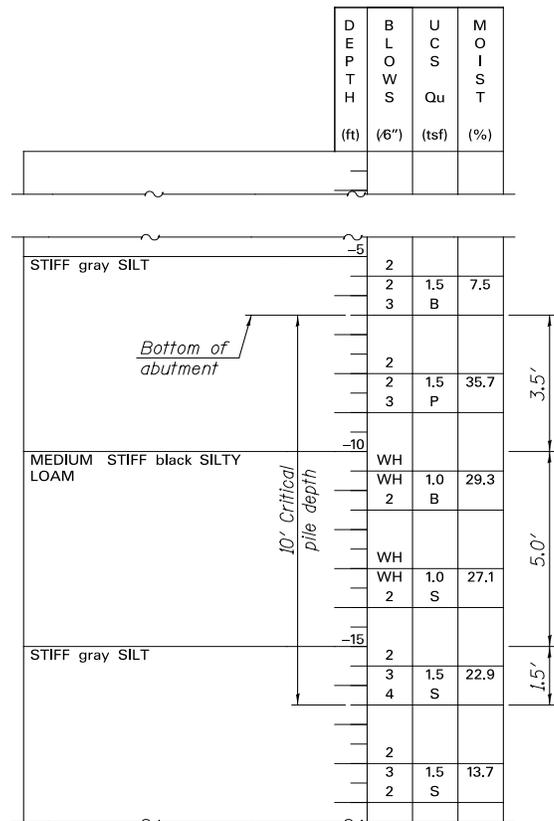
- The maximum end span permitted in a multi-span structure is 200 feet
- The maximum simple span length is 170 feet.
- End spans and simple spans exceeding 150 ft. shall only utilize HP 12 X 74 or larger piles. The maximum total slab bridge length is 130 feet
- The maximum individual slab span is 40 feet.

Example 1

The structure is a continuous 450 ft. long structure consisting of three – 150 ft. spans with a zero degree skew. The structure is the same width throughout and thus expected to have the same number of piles at each abutment. Determine the effective expansion length for the structure and whether the structure may be integral.



West Abutment Boring B-1



East Abutment Boring B-2

Determine the average Q_u for the critical pile depth at each abutment.

$$Q_{u_{west}} = \frac{(1.0)(1.5) + (2.5)(1.8) + (2.5)(1.0) + (2.5)(1.3) + (1.5)[0.75\ln(9) + 0.7]}{10}$$

$$= 1.53 \text{ (say 1.5 tsf.)}$$

$$Q_{u_{east}} = \frac{(3.5)(1.5) + (5.0)(1.0) + (1.5)(1.5)}{10} = 1.25 \text{ tsf.}$$

The average Q_u at each abutment is ≤ 1.5 tsf which is within the default parameters of the Integral Abutment Pile Selection Chart. Therefore, the controlling expansion length does not need to be adjusted by either the pile stiffness modifier or the Q_u correction factor and the effective expansion length (EEL) may be assumed to be one half the structure length (225 ft.). Applying the EEL and skew to the Integral Abutment Pile Selection Chart indicates that the HP 12x74, HP 14x73 and all pile choices above this line may be used for an integral structure. The specific pile type shall be determined by the designer based on the pile spacing and axial load.

Example 2

Use the same geometric configuration from Example 1 except that the average Q_u within the critical pile depth at the east abutment is increased from 1.25 to 2.0 tsf. Calculate the centroid of stiffness of the structure and the controlling EEL to determine whether this structure can remain integral.

Determine the pile stiffness modifier for the east abutment since it has an average $Q_u > 1.5$ tsf.

$$M_{east} = \frac{1}{1.45 - 0.3(2.0)} = 1.18$$

$$M_{west} = \frac{1}{1.45 - 0.3(1.5)} = 1.0$$

Assume 6 beam lines in the structure with a pile placed beneath each beam and calculate the centroid of stiffness from the west abutment.

$$\Sigma \text{Stiff. West Abut.} = \frac{(6 \text{ piles})(0 \text{ ft.})(1.0) + (6 \text{ piles})(1.18)(450 \text{ ft.})}{(6 \text{ piles})(1.0) + (6 \text{ piles})(1.18)} = 243.6 \text{ ft.}$$

The distance from the centroid of stiffness to the East Abutment is

$$450 - 243.6 = 206.4 \text{ ft.}$$

The distance from the centroid of stiffness to the west abutment is longer; therefore this is the controlling expansion length. Since the Q_u for the west abutment is ≤ 1.5 tsf, no Q_u correction factor adjustment to this length is necessary for determining the EEL. The EEL for the structure is therefore 243.6 ft. Based on the chart, this structure may be an integral by using either pile size of either HP12X84, HP14X89, HP14X102, or HP14X117.

Note: If Example 2 had an average Q_u within the critical pile depth at the west abutment increased from 1.5 to 2.0 tsf and from 2.0 to 2.5 tsf at the east abutment, it would require a pile stiffness modifier (>1.0) at the west abutment which would increase its the controlling expansion length from 243.6 ft. to 246.6 ft. However, this length would need to be multiplied by the Q_u correction factor, $(2.0/1.5)$ at the controlling west abutment. The EEL would therefore be 328.8 ft. and the Integral Abutment Pile Selection Chart would indicate that this structure could not be integral.

Example 3

This example is similar to Example 2 (a continuous 450 ft. long structure consisting of 3 – 150 ft. spans; average Q_u at west abutment = 1.5 tsf and average Q_u at east abutment = 2.0 tsf), except the structure is flared. The west abutment is wider than the east abutment and has 10 piles compared to 6 piles at the east abutment.

Determine the centroid of stiffness from the west abutment.

$$\sum_{\text{Stiff.W. Abut.}} = \frac{(10 \text{ piles})(0 \text{ ft.}) + (6 \text{ piles})(1.18)(450 \text{ ft.})}{(10 \text{ piles}) + (6 \text{ piles})(1.18)} = 186.5 \text{ ft.}$$

The distance from the centroid of stiffness to the centerline of the east abutment is 263.5 ft. and is the controlling expansion length. However, because the Q_u at the east abutment is 2.0 tsf, the Q_u correction factor would cause the EEL to be:

$$(263.5 \text{ ft.}) \frac{(2.0 \text{ tsf.})}{(1.5)} = 351.3 \text{ ft.}$$

The Integral Abutment Pile Selection Chart indicates that this structure cannot be integral.