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WINGWALL TYPE SELECTION FOR INTEGRAL ABUTMENT BRIDGES: SURVEY OF CURRENT PRACTICE IN THE UNITED STATES OF AMERICA

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SPECIAL REPORT 154
TRANSPORTATION RESEARCH AND DEVELOPMENT BUREAU
New York State Department of Transportation
Astrid C. Glynn, Commissioner

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Abstract

There are more than 13,000 Integral Abutment Bridges in service in the USA. A Fully Integral Abutment Bridge (FIAB) is defined as a structure where the superstructure (bridge beams and deck) is directly connected to the substructure (abutments). During thermal expansion and contraction, the superstructure and substructure move together into and away from the backfill. There are no bearings or expansion joints.

Wingwalls are a necessary component of most FIAB bridges to retain the fill that supports the roadway. Currently, wingwalls do not get a lot of attention from the designer, and are almost an afterthought to the overall design of the structure. However, wingwall orientation and connection details can have an impact on the forces induced in, and the distribution of, the forces throughout the structure.

A survey was sent to all transportation agencies in the USA and Canada concerning wingwall types used with FIAB. The survey intended to summarize the current state of practice concerning typical wingwall types and the design considerations of each agency.

The survey results indicate that there is little agreement among the various agencies as to what limits, if any, should be placed on the wingwall type, length or support condition used with FIAB. In fact, few states even consider wingwall selection in the overall performance of the structure.

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Contents

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I. Introduction

A. Background

There are more than 13,000 Integral Abutment Bridges in service in the USA *(1.)* A Fully Integral Abutment Bridge (FIAB) is defined as a structure where the superstructure (bridge beams and deck) is directly connected to the substructure (abutments). During thermal expansion and contraction, the superstructure and substructure move together into and away from the backfill. There are no bearings or expansion joints. See Figures 1 and 2 for examples of a FIAB.

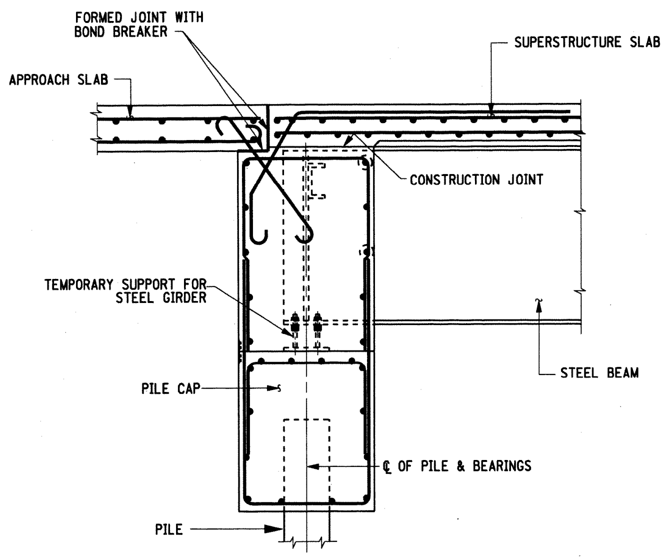

Figure 1: Example of a FIAB used by the New York State DOT, USA *(2)*

Figure 2: Example of a constructed FIAB

There have been a number of surveys of state agencies regarding the use of FIAB. Typically, these surveys involve the design and detailing of the main structural components of the FIAB. Based on these surveys and numerous research papers written on FIAB, information is readily available about the movement of the abutment stem, design of the bridge beams, or anticipated soil interaction forces. There is little information, however, about the performance of the retaining walls used with FIAB. This lack of information is surprising, since almost every FIAB uses some form of soil retaining wall system, also known as wingwalls.

The wingwalls are not the primary load carrying members of the FIAB, but their size, capacity, and connection to the main abutment stem may have a dramatic impact on the overall performance of the bridge. It is reported that 10% of the states that use integral abutments have experienced problems with cracking of the wingwalls *(1)*, indicating that further investigation into their behavior is warranted. See Figure 3 for an example of a constructed FIAB with a cantilevered flared wingwall.

Figure 3: Example of a constructed FIAB with a cantilevered flared wingwall

B. The Present Study

A survey was sent to all transportation agencies in the USA and Canada concerning wingwall types used with FIAB. The survey intended to summarize the current state of practice concerning typical wingwall types and the design considerations of each agency. The survey was made intentionally short to promote a high response rate. A copy of the survey may be found in Appendix A.

For the purposes of this report, the following definitions apply:

- A cantilevered wingwall is a retaining wall that is poured integrally with the abutment stem and thus moves with the abutment stem with respect to the soil. Cantilevered wingwalls may or may not have piles placed directly beneath the wall.
- An independently supported wingwall is a retaining wall that has its own foundation and is not connected to the moving abutment stem.
- An in-line wingwall is a retaining wall that is parallel to the centerline of bearings.

- A U-wingwall is a retaining wall that is parallel to the roadway.
- A flared wingwall is a retaining wall that lies between an inline and a U-wingwall.

II. Survey Results

A total of 34 US transportation agencies responded to the survey, resulting in an approximate response rate of 68%. Three of the agencies that responded to the survey indicated that they do not use integral abutments. Alberta, Canada also responded to the survey to bring the total of all respondents to 35. For the purposes of the remainder of this paper, only the US agencies that use FIAB will be discussed. The complete survey responses, including Alberta, are shown in Appendix B.

A. Cantilevered Wingwalls with FIAB

A cantilevered wingwall acts as a cantilevered beam supported along its attachment to the moving abutment stem and loaded by the active or passive resistance of the retained soil.

1. Cantilevered In-Line Wingwalls

Figure 4 shows, in a simple isometric view, an FIAB with a cantilevered in-line wingwall. The abutment stem is able to rotate and translate laterally into and away from the retained soil.

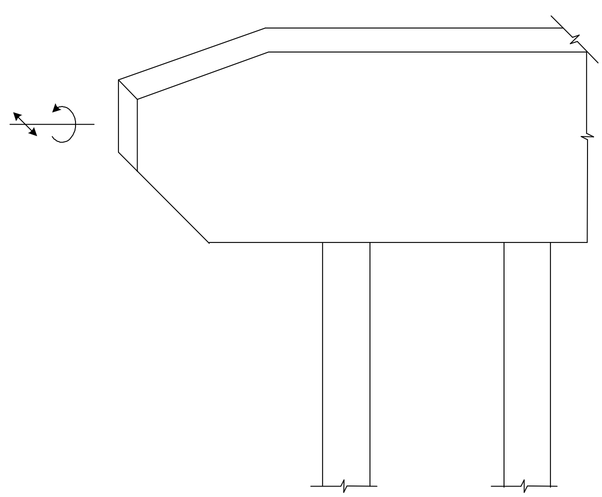

Figure 4: Simple diagram of an FIAB with a cantilevered in-line wingwall

As indicated in Figure 5, 64.5% of the USA respondents permit the use of cantilevered in-line wingwalls with FIAB. In the US, most FIAB are founded on piles. Figure 6 shows that 35% of the agencies that permit the use of cantilevered in-line wingwalls permit piles to be placed beneath the wingwalls.

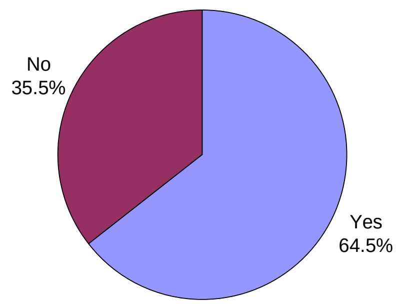

Figure 5: Percentage of agencies that permit the use of cantilevered in-line wingwalls

As mentioned earlier, in-line wingwalls do not restrain the rotation of the FIAB stem. The issue to consider when allowing piles to be placed beneath a cantilevered in-line wingwall is that in order to move along with the abutment stem, the wingwall must now also overcome the resistance of the piles in addition to the soil forces.

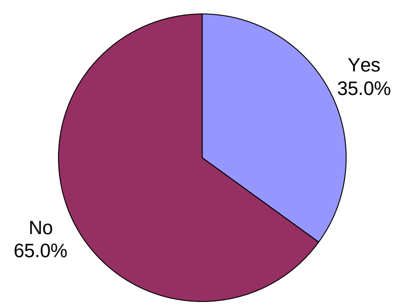

Figure 6: Out of those that permit the use of cantilevered in-line wingwalls, percentage of agencies that permit piles to be placed under the cantilevered in-line wingwall

While a few agencies require a minimum of one pile beneath the wingwall, most did not. Some agencies limited the maximum number of piles to one or two, but most did not limit the number of piles placed beneath the cantilevered in-line wingwall.

2. Cantilevered U-Wingwalls

Figure 7 shows, in a simple isometric view, an FIAB with a cantilevered U-wingwall.

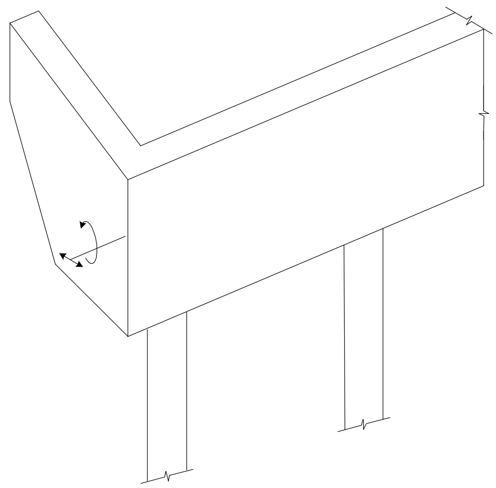

Figure 7: Simple diagram of an FIAB with a cantilevered flared wingwall

When used with a single row of piles, as shown in Figure 8, the abutment stem is able to rotate and translate laterally into and away from the retained soil while only having to overcome the passive resistance of the retained soil and the bearing pressure of the soil beneath the U-wingwall.

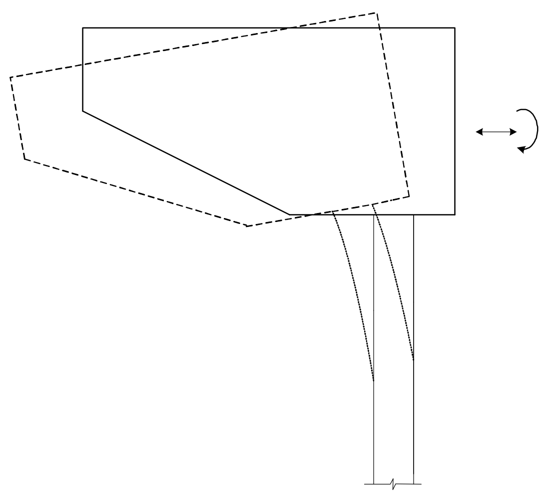

Figure 8: Relatively free rotation of an FIAB with cantilevered U-wingwalls on a single row of piles

Figure 9 illustrates how piles placed beneath a cantilevered U-wingwall restrict the movement of the abutment stem to mostly lateral motion and induces additional down-force or uplift on the piles. The prevention of abutment rotation results in greater end moments for the main structural beams and deck slab, and also induces bending and shear forces into the wingwall.

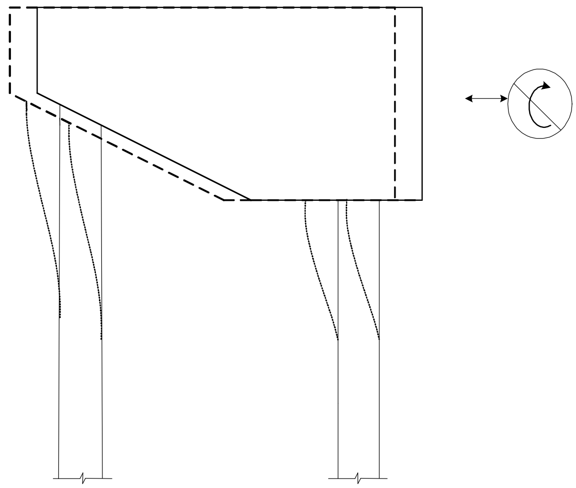

Figure 9: Restrained rotation of an FIAB with pile supported U-wingwalls

Figure 10 indicates that 80.6% of the USA respondents permit the use of cantilevered U-wingwalls with FIAB. Figure 11 shows that of those that permit their use, 20% permit piles to be placed beneath the cantilevered U-wingwall.

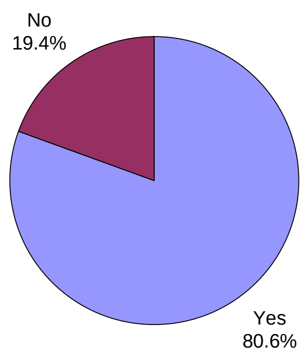

Figure 10: Percentage of agencies that permit the use of cantilevered U-wingwalls

While two agencies required a minimum of one pile beneath the U-wingwall, one agency required there to be exactly two piles in every case. The most common reason for requiring the piles to be placed near the end of the wingwall was to facilitate construction by providing something solid to anchor the concrete formwork.

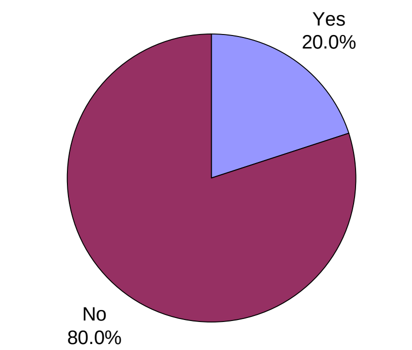

Figure 11: Out of those that permit the use of cantilevered U-wingwalls, percentage of agencies that permit piles to be placed under the cantilevered U-wingwall

Figure 12 shows that of the agencies that permit piles beneath the cantilevered U-wingwalls, 40% accounted for the restrained rotation. The predominate reason given for ignoring these forces is that in-field performance indicates that the current designs are capable of resisting these forces, even if they are not explicitly accounted for in the design.

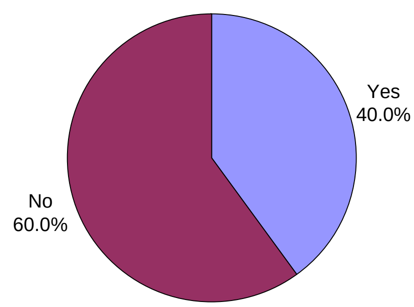

Figure 12: Out of those that permit the use of cantilevered U-wingwalls, percentage of agencies that account for restrained rotation of pile supported cantilevered U-wingwalls

3. Cantilevered Flared Wingwalls

Figure 13 shows, in a simple isometric view, an FIAB with a cantilevered flared wingwall. When used with a single row of piles, the abutment stem is able to rotate and translate laterally into and away from the retained soil while only having to overcome the passive resistance of the retained soil and the bearing pressure of the soil beneath the flared wingwall.

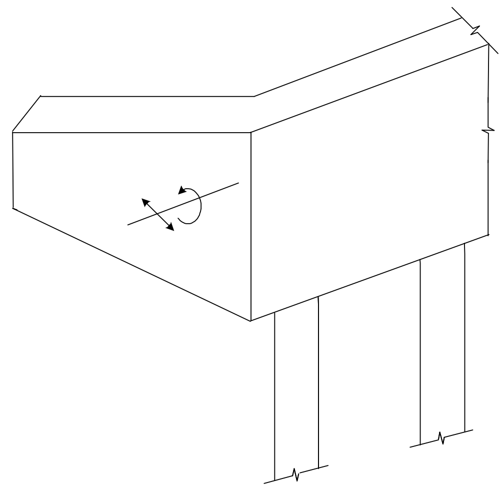

Figure 13: Simple diagram of an FIAB with a cantilevered flared wingwall

Figure 14 illustrates that 32.3% of the USA respondents permit the use of cantilevered flared wingwalls with FIAB.

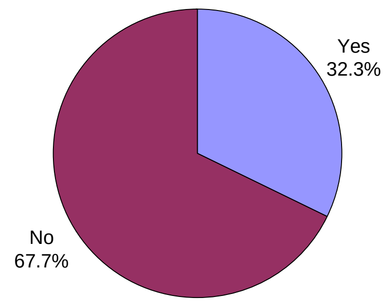

Figure 14: Percentage of agencies that permit the use of cantilevered flared wingwalls

Placing a pile beneath a cantilevered flared wingwall restricts the ability of the abutment stem to accommodate the beam end rotations. This restricts the movements to mostly lateral motion, induces additional compressive load or uplift on the piles, and results in greater end moments for the beams and deck slab. Wisconsin DOT permits there to be one pile placed beneath the cantilevered flared wingwalls. They are the only state to permit any piles to be placed beneath the flared cantilever wingwall, as shown in Figure 15. They further state that they do account for the restrained rotation of the abutment stem.

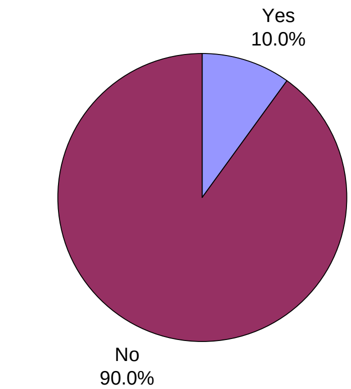

Figure 15: Out of those that permit the use of cantilevered flared wingwalls, percentage of agencies that permit piles to be placed under the cantilevered flared wingwalls

B. Independently Supported Wingwalls with FIAB

An independently supported wingwall is not rigidly attached to the FIAB. Instead, the wingwall is founded on its own independent foundation. The abutment stem is free to translate or rotate with the superstructure without contribution or resistance from the wingwall system. The wingwall foundation may be of any type, including a single row of piles, multiple rows of piles, spread footings, Mechanically Stabilized Earth Structure (MSES), or some other type. Independently supported wingwalls are normally used with FIAB when the wingwall becomes so long that it is difficult to design as a cantilever. Michigan DOT and Nebraska DOT are exceptions to this rule, as they only permit independently supported wingwalls to be used with FIAB.

1. Independently Supported In-Line Wingwalls

More than 35% of the US respondents permit the use of independently supported in-line wingwalls with FIAB, as shown in Figure 16. Of those agencies that specified a length threshold, most agencies stated that they would not consider an independently supported in-line wingwall until the wall length exceeded 12 ft. (3.7 m).

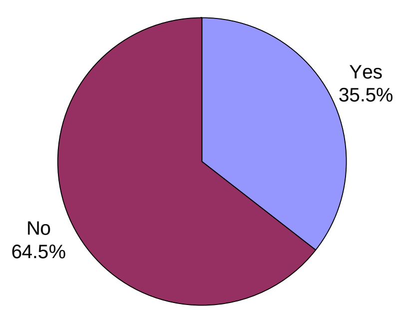

Figure 16: Percentage of agencies that permit the use of independently supported in-line wingwalls

2. Independently Supported U-Wingwalls

Figure 17 indicates that 58.1% of the US respondents permit the use of independently supported U-wingwalls with FIAB. There did not seem to be much consensus on when the U-wingwall should be placed on its own independent foundation. Of those agencies that specified a length threshold, the lowest value was 5 ft. (1.5 m).

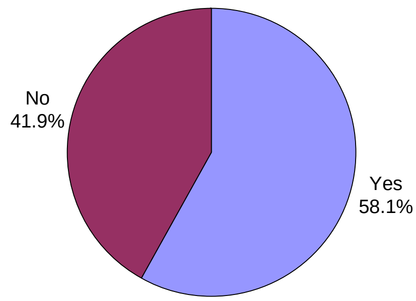

Figure 17: Percentage of agencies that permit the use of independently supported U-wingwalls

3. Independently Supported Flared Wingwalls

Figure 18 shows that almost 42% of the respondents permit the use of independently supported flared wingwalls with FIAB. Of those agencies that specified a point at which they would require the cantilevered flared wingwall to be placed on its own foundation, the lowest length threshold was 5 ft. (1.5 m).

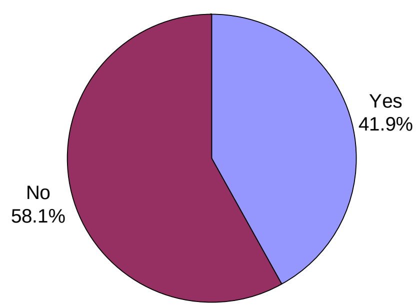

Figure 18: Percentage of agencies that permit the use of independently supported flared wingwalls

III. Discussion

Wingwalls are necessary components of most FIAB bridges to retain the fill that supports the roadway. Wingwall orientation and connection details may have a dramatic impact on the magnitude and distribution of forces throughout the structure. Currently, wingwalls are designed to resist the forces applied to them, but the forces that the wingwalls may be exerting on the overall structure does not typically get a lot of attention from the bridge engineer.

Obviously, a FIAB must be designed to withstand the forces to which it is subjected. Many transportation agencies accomplish this requirement by restricting the span length, deck width, skew angle, or other criteria to minimize the induced loads. Instead of explicitly accounting for the forces that are generated, they use their experience to limit the geometry of the system such that the resulting forces are low enough to be handled using standard details and conservative design assumptions that have proven reliable in the past. These designs are capable of accomplishing the overall goal of a safe and low-maintenance structure without requiring the use of an intensive computer model to analyze the actual complex structural system.

FIAB have proven to be economical, durable, and reliable. As the inventory of FIAB grows, there is a natural tendency to become comfortable with the success of the FIAB concept and expand the limitations placed on their use. By doing so, FIAB will be used in locations where they would have previously been restricted. The resulting structures will generate larger movements, rotations, and forces than those that have been previously constructed. These larger structures may exceed the capacity of the standard details that have proven so reliable in the past. The result may be an unconservative design for either the wingwalls or to the overall system which they are attached.

To insure safe and reliable performance, the FIAB should be designed as a complete system that works together, rather than as a series of individual components that happen to be connected. Each component should be investigated as to how it affects the overall structure. Wingwalls and their supporting structure have the potential to restrict or even prevent the translations and rotations of the superstructure and abutment stem, which could significantly impact the overall performance of the entire FIAB, and should be investigated accordingly.

IV. Conclusion

Cantilevered in-line wingwalls behave as cantilevered beams subjected to their own vertical dead load and the horizontal pressure exerted by the retained soil. Placing piles beneath the wingwalls complicates the analysis, since the moving wingwalls must not only overcome the resistance of the soil, but also the resistance of the piles.

Cantilevered U-wingwalls and cantilevered flared wingwalls are more complicated in that they are subjected to all of the same forces as in-line wingwalls, plus an additional load from the bearing resistance of the soil beneath the rotating wingwalls. As the abutment stem rotates, the wingwalls are resisted by passive resistance of the retained soil and the bearing resistance of the soil beneath the wingwalls.

Additional forces are introduced into the overall structural system when piles are placed beneath the wingwalls. The piles create a moment couple that prevents rotation of the abutment stem. These restrained rotations create internal forces that must be accommodated somewhere in the structural system.

As evidenced by the survey, there is little agreement among the various agencies as to what limits, if any, should be placed on the wingwall type, length or support condition used with

FIAB. In fact, few states even consider wingwall selection in relation to the overall performance of the structure.

V. Future Research

It is recommended that a parametric study be conducted using Finite Element Modeling (FEM) to determine the effect that wingwall type, orientation and rigidity have on the overall structural system of a FIAB. FEM is preferable to field instrumentation of a real structure, since the computer models can analyze dozens of structures that differ only in the geometry and structural capacity of the wingwall system. Conclusions on the effects of the different wingwalls can then be drawn by comparing the results of the different FEM models. The results of the study may lead to recommendations on design and detailing changes for FIAB to minimize or account for the effects of various wingwall configurations.

A subsequent research project may be initiated where an actual structure is constructed using the design and detailing guidelines suggested by the parametric study. That structure should be modeled using FEM and field instrumented. The field instrumentation will provide data to calibrate and refine the FEM methodology. The calibrated model may either provide greater confidence in the guidelines recommended in the initial parametric study, or suggest modifications to achieve more accurate results.

Acknowledgements

This author wishes to thank the agency engineers that so thoughtfully completed the questionnaire and responded to the follow-up phone interviews. The paper would not have been possible without their efforts. In addition, thanks go out to Mr. Jon Kunin for his assistance and support during the writing and editing of this paper.

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2. *NYSDOT Bridge Manual – 3rd Edition*, 2005, New York State Department of Transportation

3. Kunin J., Alampalli S., 1999, *Integral Abutment Bridges: Current Practice in the United States and Canada*, Report FHWA/NY/SR-99/132

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Appendix A

Study Survey

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Integral Abutment Wingwall Survey

Name: ______________________________ Position: ____________________________

Agency: ____________________________ Address: ____________________________

Phone: ______________________________ E-mail: _____________________________

Please respond by October 22, 2007. Send completed surveys to by e-mail to HWHITE@dot.state.ny.us, by Fax at 518.457.7535, or by regular mail at the address on the cover letter. Thank you for contributing to the body of knowledge of Integral Abutments.

Does your Agency permit the use of cantilevered in-line wingwalls with IAB?
Yes No

If so, does your agency permit piles to be placed beneath the cantilevered in-line wingwall?
Yes (How many? _____min. _____max.) No NA

Does your Agency permit the use of independently supported in-line wingwalls with IAB?
Yes No

If so, how long does the in-line wingwall have to be before using an independently supported foundation?

Does your Agency permit the use of cantilevered flared wingwalls with IAB?
Yes No

If so, does your Agency permit piles to be placed beneath the cantilevered flared wingwall?
Yes (How many? _____min. _____max.) No NA

If piles are permitted beneath the cantilevered flared wingwall, how is the restrained rotation of the abutment stem accounted for in the design?____
____

Does your Agency permit the use of independently supported flared wingwalls with IAB?
Yes No

If so, how long does the flared wingwall have to be before using an independently supported foundation?

Does your Agency permit the use of cantilevered U-wingwalls with IAB?
Yes No

If so, does your agency permit piles to be placed beneath the cantilevered U-wingwall?
Yes (How many? _____min. _____max.) No NA

If piles are permitted beneath the cantilevered U-wingwall, how is the restrained rotation of the abutment stem accounted for in the design? ____
____

Does your Agency permit the use of independently supported U-wingwalls with IAB?
Yes No

If so, how long does the U-wingwall have to be before using an independently supported foundation?

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Appendix B

Results of the Survey

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	Permit the use of cantilevered In-Line Wingwalls with IAB?	Permit piles to be placed beneath the cantilevered Wingwalls?	Minimum Number of piles?	Maximum Number of piles?	Permit the use of independently supported In-Line Wingwalls with IAB?	How Long Does the Wingwall have to be Before Using an Independent Foundation (ft.)?
Arizona	Yes	No	N/A	N/A	No	N/A
Arkansas	No	N/A	N/A	N/A	No	N/A
California	Yes	No	N/A	N/A	Yes	20
Hawaii	Yes	No	N/A	N/A	Yes	No Limit
Illinois	Yes	No	N/A	N/A	No	N/A
Indiana	No	N/A	N/A	N/A	No	N/A
Iowa	No	N/A	N/A	N/A	No	N/A
Maryland	Yes	Yes	0	No Limit	No	N/A
Michigan	No	N/A	N/A	N/A	Yes	No Limit
Minnesota	Yes	No	N/A	N/A	No	N/A
Missouri	No	N/A	N/A	N/A	No	N/A
Montana	Yes	No	N/A	N/A	No	N/A
Nebraska	No	N/A	N/A	N/A	No	N/A
New Jersey	Yes	No	N/A	N/A	Yes	12
NJ Turnpike	Yes	No	N/A	N/A	Yes	12
New Mexico	Yes	No	N/A	N/A	Yes	No Limit
New York	Yes	No	N/A	N/A	Yes	12
North Carolina	No	N/A	N/A	N/A	No	N/A
North Dakota	Yes	No	N/A	N/A	No	N/A
Ohio	Yes	Yes	0	No Limit	No	N/A
Oklahoma	No	N/A	N/A	N/A	No	N/A
Pennsylvania	No	N/A	N/A	N/A	No	N/A
South Carolina	No	N/A	N/A	N/A	Yes	ALL
South Dakota	Yes	Yes	1	2	No	N/A
Tennessee	Yes	Yes	0	No Limit	No	N/A
Utah	No	N/A	N/A	N/A	No	N/A
Vermont	Yes	Yes	0	No Limit	Yes	10

	Permit the use of cantilevered In-Line Wingwalls with IAB?	Permit piles to be placed beneath the cantilevered Wingwalls?	Minimum Number of piles?	Maximum Number of piles?	Permit the use of independently supported In-Line Wingwalls with IAB?	How Long Does the Wingwall have to be Before Using an Independent Foundation (ft.)?
Virginia	Yes	No	N/A	N/A	Yes	No Limit
West Virginia	Yes	Yes	0	No Limit	Yes	No Limit
Wisconsin	Yes	Yes	0	No Limit	No	N/A
Wyoming	Yes	No	N/A	N/A	No	N/A
Alberta, Canada	Yes	Yes	1	No Limit	No	N/A

	Permit the Use of Cantilevered Flared Wingwalls With IAB?	Permit piles to be Placed Beneath the Cantilevered Flared Wingwalls?	Minimum Number of piles?	Maximum Number of piles?	Is Restrained Rotation Accounted For In the Design?	Permit the Use of Independently Supported Flared Wingwalls with IAB?	How Long Does the Wingwall Have to be Before Using an Independent Foundation (ft.)?
Arizona	Yes	No	N/A	N/A	N/A	Yes	10
Arkansas	No	N/A	N/A	N/A	N/A	No	N/A
California	Yes	No	N/A	N/A	N/A	Yes	20
Hawaii	Yes	No	N/A	N/A	N/A	Yes	No Limit
Illinois	No	N/A	N/A	N/A	N/A	No	N/A
Indiana	No	N/A	N/A	N/A	N/A	No	N/A
Iowa	No	N/A	N/A	N/A	N/A	No	N/A
Maryland	No	N/A	N/A	N/A	N/A	Yes	5
Michigan	No	N/A	N/A	N/A	N/A	Yes	No Limit
Minnesota	Yes	No	N/A	N/A	N/A	No	N/A
Missouri	No	N/A	N/A	N/A	N/A	No	N/A
Montana	No	N/A	N/A	N/A	N/A	No	N/A
Nebraska	No	N/A	N/A	N/A	N/A	No	N/A
New Jersey	Yes	No	N/A	N/A	N/A	Yes	No Limit
NJ Turnpike	No	N/A	N/A	N/A	N/A	Yes	No Limit
New Mexico	No	N/A	N/A	N/A	N/A	No	N/A
New York	Yes	No	N/A	N/A	N/A	Yes	12
North Carolina	No	N/A	N/A	N/A	N/A	No	N/A
North Dakota	No	N/A	N/A	N/A	N/A	No	N/A
Ohio	No	N/A	N/A	N/A	N/A	No	N/A
Oklahoma	No	N/A	N/A	N/A	N/A	No	N/A
Pennsylvania	No	N/A	N/A	N/A	N/A	No	N/A
South Carolina	No	N/A	N/A	N/A	N/A	Yes	ALL
South Dakota	No	N/A	N/A	N/A	N/A	No	N/A
Tennessee	No	N/A	N/A	N/A	N/A	Yes	—
Utah	No	N/A	N/A	N/A	N/A	No	N/A
Vermont	Yes	No	N/A	N/A	N/A	Yes	10

	Permit the Use of Cantilevered Flared Wingwalls With IAB?	Permit Piles to be Placed Beneath the Cantilevered Flared Wingwalls?	Minimum Number of Piles?	Maximum Number of Piles?	Is Restrained Rotation Accounted For in the Design?	Permit the use of Independently Supported Flared Wingwalls with IAB?	How Long Does the Wingwall Have to be Before Using an Independent Foundation (ft.)?
Virginia	Yes	No	N/A	N/A	N/A	Yes	No Limit
West Virginia	Yes	No	N/A	N/A	N/A	Yes	No Limit
Wisconsin	Yes	Yes	1	1	Yes	No	N/A
Wyoming	No	N/A	N/A	N/A	N/A	N/A	N/A
Alberta, Canada	Yes	Yes	1	No Limit	No	No	N/A

	Permit the Use of Cantilevered U-Wingwalls With IAB?	Permit piles to be Placed Beneath the Cantilevered U-Wingwalls?	Minimum Number of piles?	Maximum Number of piles?	Is Restrained Rotation Accounted For in the Design?	Permit the Use of Independently Supported U-Wingwalls with IAB?	How Long Does the U-Wingwall Have to be Before Using an Independent Foundation (ft.)?
Arizona	Yes	No	N/A	N/A	N/A	No	N/A
Arkansas	Yes	No	N/A	N/A	N/A	No	N/A
California	Yes	No	N/A	N/A	N/A	Yes	20
Hawaii	Yes	No	N/A	N/A	N/A	Yes	No Limit
Illinois	No	N/A	N/A	N/A	N/A	No	N/A
Indiana	Yes	No	N/A	N/A	N/A	No	N/A
Iowa	Yes	Yes	2	2	No	Yes	5
Maryland	No	N/A	N/A	N/A	N/A	Yes	5
Michigan	No	N/A	N/A	N/A	N/A	Yes	No Limit
Minnesota	Yes	No	N/A	N/A	N/A	No	N/A
Missouri	Yes	No	N/A	N/A	N/A	Yes	22
Montana	Yes	Yes	1	1	Yes	No	N/A
Nebraska	No	No	N/A	N/A	N/A	Yes	ALL
New Jersey	Yes	No	N/A	N/A	N/A	Yes	10
NJ Turnpike	Yes	No	N/A	N/A	N/A	Yes	6
New Mexico	yes	No	N/A	N/A	N/A	Yes	No Limit
New York	Yes	No	N/A	N/A	N/A	Yes	6
North Carolina	Yes	No	N/A	N/A	N/A	No	N/A
North Dakota	Yes	No	N/A	N/A	N/A	No	N/A
Ohio	No	N/A	N/A	N/A	N/A	No	N/A
Oklahoma	Yes	No	N/A	N/A	N/A	No	N/A
Pennsylvania	Yes	No	N/A	N/A	N/A	Yes	10
South Carolina	Yes	No	N/A	N/A	N/A	Yes	10
South Dakota	Yes	No	N/A	N/A	N/A	No	N/A
Tennessee	Yes	Yes	1	1	No	Yes	20
Utah	Yes	Yes	0	1	No	Yes	—
Vermont	Yes	No	N/A	N/A	N/A	Yes	10

	Permit the Use of Cantilevered U-Wingwalls With IAB?	Permit piles to be Placed Beneath the Cantilevered U-Wingwalls?	Minimum Number of piles?	Maximum Number of piles?	Is Restrained Rotation Accounted For In the Design?	Permit the Use of Independently Supported U-Wingwalls with IAB?	How Long Does the U-Wingwall Have to be Before Using an Independent Foundation (ft.)?
Virginia	Yes	No	N/A	N/A	N/A	Yes	8
West Virginia	Yes	No	N/A	N/A	N/A	Yes	No Limit
Wisconsin	Yes	Yes	0	1	Yes	No	N/A
Wyoming	No	N/A	N/A	N/A	N/A	No	N/A
Alberta, Canada	Yes	Yes	1	1	No	No	N/A