Illinois Department of Transportation

Memorandum

To: ALL BRIDGE DESIGNERS 08.1

From: Ralph E. Anderson Ralph E. Anderson

Subject: Evaluating Existing Substructures for Reuse

Date: February 20, 2008

For many years the Department has successfully allowed existing substructures to be re-used without a detailed structural analysis when they were in good or repairable condition and the proposed dead load was not greater than 110% of the existing dead load. This practice was primarily based on the assumption that the actual live load carried by the substructure would remain the same and the increased dead load would result in only a minor safety factor decrease with negligible foundation settlement. With the change to LRFD, increased deck thickness, heavier deck beams, additional wearing surfaces, and an increased need to reuse existing foundations, it has now become necessary to provide more detailed guidelines on how to evaluate existing substructures for reuse.

The following new guidelines are intended to supersede the current “Condition” and “Load Capacity” provisions found under Substructure Evaluation in the BRIDGE CONDITION REPORT PROCEDURES & PRACTICES (Feb. 2007).

ABBREVIATED ANALYSIS

The load capacity of existing foundation and substructure elements may be assumed to be adequate for reuse without a detailed structural analysis when:

- The substructure elements are in good condition (Condition Rating of 6 or higher).
- The proposed service dead load is not greater than 115 percent of the original service dead load at the top of the substructure.
- There is no significant reconfiguration of loads (i.e. changes to bearing locations or pier fixities)
- The substructure shows no distress under existing live loading.

DETAILED ANALYSIS

If a structure does not satisfy the criteria outlined for an Abbreviated Analysis, a detailed check of the existing substructure elements (caps, columns, pier stems, footings, etc) and the foundation elements (pile and spread footing foundations) shall be performed as follows:

Substructure Elements

Caps, Columns, Pier Stems, Footings, etc.: A detailed capacity check of the existing substructure elements shall be performed utilizing an Illinois modified Group 1 load combination per the AASHTO LFD Bridge Design Specifications. The analysis shall consider all applicable dead loads and the effects of the HS-20 live load configuration. As a minimum, the substructure elements shall be investigated for the Standard Specifications, Division 1A, 500 year seismic hazard. Please refer to the FHWA Seismic Retrofitting Manual for Highway Bridges (May 1995) for recommendations as necessary. Certain structures may require additional seismic upgrades depending upon the importance classification of the structures as determined by the owner. The Illinois modified load combination shall be as follows:

1.15 x (DL) + 1.3 x (5/3 x (LL))

If a substructure element is still deficient after a detailed analysis, consider:

1. Reducing dead loads. (i.e. reduce or eliminate FWS; change parapet to railing; etc.)
2. Investigating individual substructure element replacement, improvement, or retrofit based on an economic study. All replacement elements shall be designed LRFD.
3. Total replacement.

Any of the above approaches are subject to the approval of the Bureau of Bridges and Structures, Planning Section.

Foundation Elements

Pile foundations: Existing piles inherently provide a time tested demonstration of their capacity, unlike recently driven, yet to be loaded, piles. Factors such as construction overdriving, driving formula conservatism, high efficiency hammer use, and development of soil setup often result in a geotechnical resistance much larger than specified on the existing plans. When existing production pile driving data is available, the larger “as driven” pile resistance may be used rather than the plan design capacity. Piles driven with an Air-Steam or Single Acting Diesel hammer have more capacity than those installed with Closed End Diesel or Drop/Gravity hammers which are less efficient in transferring energy to the pile. Another source of extra capacity exists in piles driven to ASD capacities below 40 tons, since this is the range where the ENR driving formula errors on the conservative side. Longer piles provide more setup opportunity and often exhibit a larger factor of safety than indicated by the driving formula. In addition, when existing soil borings are available or new soil borings can be obtained, the mode of support and extent of setup may be inferred. Piles driven to shale bedrock are least likely to provide any setup while the nominal capacities of piles driven to dolomite or limestone are normally controlled by the piles structural capacity. Piles supported mainly by side resistance provide the most set up and when the side resistance is provided by cohesive soils, the amount of setup assumed may be further increased. The attached "Existing Pile Capacity Determination Table" and corresponding example provide a method to determine the increased geotechnical resistance that can be utilized when the various factors are present.

Spread footing foundations: In most cases spread footings have been used at bridge substructures only when rock or extremely dense soils are present. Although this was typically done to avoid settlement concerns, these spread footings often have additional geotechnical strength capacity and can support increased structure loadings with negligible additional settlement. Unlike piles, the existing plans often provide inaccurate or no information concerning the footing bearing capacity. Thus, in order to determine a bearing capacity, it is necessary to gather as much information about the footing geometry and subsurface soil/rock conditions as possible. The attached "Existing Spread Footing Capacity Determination Table" and corresponding example provide a method to determine the geotechnical resistance that can be utilized when various factors are present. Settlement need not be checked since the loadings are not expected to substantially increase, the foundation materials have been preloaded and the load capacity increase is limited using the procedure included herein.

For both piles and spread footings lateral loads to piles or sliding need not be checked unless the structure is in seismic categories C or D. The allowable resistance available may be converted to factored resistance by multiplying by 1.5 (3.0 Factor of Safety times a 0.5 resistance factor). The foundation element may be re-used providing the following conditions exist:

1. The Illinois modified Group 1 load combination is below the actual calculated resistance available from the existing foundation as described in this memo.
2. The hydraulics analysis and soil conditions indicate no substantial scour.
3. No corrosion or rotting has compromised the structural integrity of the piles or footing.
4. Inspections indicate no past foundation settlement.
5. There is sufficient redundancy (More than 4 piles exist in the pile foundations).
6. The increase in pile capacity or service bearing loading does not exceed 50%

Any questions can be directed to Ben Garde of our Bridge Planning Unit at 217-524-4848 or Ben.Garde@illinois.gov or Bill Kramer of our Central Geotechnical Unit at 217-782-7773 or William.kramer@illinois.gov.

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Existing Pile Capacity Determination Table

C_s	**Existing Pile Capacity Source**	Existing Driving Records (**0**% Capacity Increase)	Existing Plans Pile Data (**10**% Capacity Increase)				
C_b	**Low Capacity Formula Bias**	Pile Capacity > 40 tons (**0**% Capacity Increase)	Pile Capacity < 40 tons (**6**% Capacity Increase)				
H_e	**Hammer Efficiency Correction**	Closed End Diesel, Drop or Unknown Hammer (**0**% Capacity Increase)	Open End Diesel Hammer (**4**% Capacity Increase)	Air-Steam Hammer (**8**% Capacity Increase)			
P_e	**Pile Effect on Hammer Efficiency**	Precast Concrete or Timber Pile (**0**% Capacity Increase)	Metal Shell or Steel H-Pile (**4**% Capacity Increase)				
P_l	**Pile Length Formula Conservatism**	Driven or Estimated Length < 60 ft. (**0**% Capacity Increase)	Estimated Plan Pile Length > 60 ft. (**2**% Capacity Increase)	Driving Records Driven Length > 60 ft. (**4**% Capacity Increase)			
S_m	**Borings Indicate Main mode of Support**	No Records Available (**0**% Capacity Increase)	End Bearing in Soil or Shale (**4**% Capacity Increase)	Friction in Granular Soils (**8**% Capacity Increase)	Friction in Cohesive Soils (**16**% Capacity Increase)	End Bearing in Sandstone (**16**% Capacity Increase)	End Bearing in Limestone or Dolomite (**20**% Capacity Increase)

Example: Existing plans pile data indicate timber piles, estimated to be 62ft long, with a design capacity of 24 tons. The pile driving records indicate that a MKT 11B3, a Closed End Air-Steam hammer, was used and on average the piles were driven 57ft with a final bearing of 30 tons.

The allowable resistance available $\mathbf{R_a}$ can be determined by the following formula $\mathbf{R_a}$ = **Existing Capacity** x (1+$\mathbf{C_s}$+$\mathbf{C_b}$+$\mathbf{H_e}$+$\mathbf{P_e}$+$\mathbf{P_l}$+$\mathbf{S_m}$). The Exist Cap = 30 tons, from driving records, $\mathbf{C_s}$ **=** 0.00, since we have driving records, $\mathbf{C_b}$ **=** 0.06, because the Exist Capacity is below 40 tons, $\mathbf{H_e}$ = 0.08, due to the use of an Air-Steam Hammer, $\mathbf{P_e}$ = 0.00, because timber piles were used, $\mathbf{P_l}$ = 0.00 due to the driven length being less than 60 feet, and $\mathbf{S_m}$ = 0.00 as no borings are available. The factored resistance available $\mathbf{R_F}$ is determined by multiplying by the factor of safety which is assumed to be 3.0 and the resistance factor with is taken as 0.5.

R_a= 30 tons x (1+0+.06+.08+ 0+0+0) = 30 tons x (1.14) = 34.2 tons 14% < 50% so Ok.
R_F = R_a x (Safety Factor) x (Resistance Factor) = 34.2 x (3) x (0.5) x (2 kips/ton) = 102.6 kips

The new factored strength group pile loading must not exceed the factored resistance available of 102.6 kips.

Existing Spread Footing Capacity Determination Table

R_a	No Borings Available (**2 ksf**)	Mixed soils with N >15 (**4 ksf**)	Clay soils with Q > 3.0 (**6 ksf**)	Very Dense Granular with N>50 (**8 ksf**)	Hard Clay Till with Qu > 4.5 tsf (**10 ksf**)	Sandstone or Shale (**15 ksf**)	Limestone or Dolomite (**30 ksf**)

Example: Obtain the footing plan dimensions and base elevation from the existing plans. Calculate the existing and proposed footing loading to obtain the maximum applied service bearing pressure ($\mathbf{Q_{MAX}}$) and resultant eccentricity. If the proposed Q max is more than 50% above the existing loading, the footing can not be reused. If founded on soil, calculate the proposed equivalent uniform bearing pressure ($\mathbf{Q_{EUBP}}$). Using new or existing boring data, locate the footing base elevation and evaluate the soils/rock within a depth of 1½ times the footing width to determine the allowable **service bearing capacity** $\mathbf{R_a}$ from the above table.
*The proposed applied bearing pressure (**Q** $_{MAX}$ for rock or **Q** $_{EUBP}$ for soil) must be less than the allowable service bearing capacity* $\mathbf{R_a}$ *and the proposed resultant eccentricity must be within the Middle third (for soil) or middle half (for rock) of the footing for the existing foundation to be considered adequate.*