Performance Measures

for Steel Pipe Pile/Concrete Pile Cap Bridge Support Systems:

Confirmation of Connection Performance

The Montana Department of Transportation (MDT) has found concrete-filled steel tube (CFT) piles connected at the top by a concrete pile cap to be a very cost effective support system for short and medium span bridges. This type of system offers low initial cost, short construction time, low maintenance requirements, and a long service life. From a structural engineering perspective, these systems must provide acceptable performance under gravity (i.e., self weight and vehicle loads) and lateral loads (i.e., extreme ice, wind, and seismic events). While the gravity load performance of these systems is well understood, their strength and ductility under extreme lateral loads is more difficult to reliably predict using conventional design procedures. Therefore, MDT sponsored three phased research projects at Montana State University (MSU) to investigate the performance of these systems under extreme lateral loads.

Based on the results of the first two phases of research, in conjunction with established structural engineering principles, MDT developed a design procedure to determine the reinforcing steel required in the pile cap to produce the desired system performance under lateral loads. The objective of the project phase reported on herein was to validate this new connection design methodology by physically testing connections designed according to this procedure. A total of six half-size connection specimens were tested under axial and lateral load until failure. Based on the results of this investigation, several observations were made regarding the efficacy of the MDT design methodology, and suggestions were made to improve its effectiveness. MDT plans on implementing the recommended modifications to this design guide; this process is currently underway.

With the completion of this project, MDT is now more confident using this system in typical bridge projects, and therefore more apt to use it and realize the cost-savings and benefits associated with it.

The potential cost-savings of this system were calculated by comparing the cost of this system to a drilled-shaft system commonly used by MDT. In particular, the following assumptions were made:

1. A single 6-foot diameter drilled concrete shaft and column system was compared to a driven CFT pile system with five 20-inch diameter piles. This analysis showed a potential cost-savings of $50,000 per bridge for the CFT pile system (Table 1 and 2).
2. It is anticipated that this system will now be used approximately 2 times per year in place of the drilled-shaft system, for a total of $100,000 per year in savings.
3. The life of this research product (new CFT connection design methodology) is anticipated to be 20 years.
4. A discount rate of 5% and an inflation rate of 3% were used to determine the present value of the research cost and future value of the benefits.

Calculations:

While the research was initiated in 2009 at a cost of $115,382, the estimation of the design savings were estimated in 2013 dollars. As a result, the 2009 research cost was updated to a present value, using the following equation:

$$Present\ value\ of\ research\ cost = \mathrm{P} * (1 + \mathrm{s})^n * (1 + r)^n$$

where: P = Initial cost of research, r is the discount rate, n is the number of years, and s is the inflation rate.

Based on this equation, the present value of the research cost in 2013 was computed as:

$$Present\ value\ of\ research\ cost = \$115{,}382 * (1 + 0.03)^n * (1 + 0.05)^n = \$157{,}851$$

The present discounted value of future benefits was calculated according to the following equation.

$$Present\ discounted\ value\ of\ future\ benefits = Benefit = \sum_{n=0}^{t} \frac{Q}{(1 + r)^n}$$

where: Q is the estimated savings per year, and t is the total number of years over which these savings will be calculated. When applied to this project, this benefit was computed as:

$$Present\ discounted\ value\ of\ future\ benefits = Benefit = \sum_{n=0}^{20} \frac{100{,}000}{(1 + 0.05)^n} = \$1{,}346{,}221$$

Results:

The Benefit to cost ratio was calculated as follows:

$$\frac{Benefit}{Cost} = \frac{\$1{,}346{,}221}{\$157{,}851} = 8.53{:}1$$

The return on investment (ROI) was calculated as:

$$ROI = \frac{(Gain\ on\ Investment - Cost\ of\ Investment)}{Cost\ of\ Investment} = \frac{(\$1{,}070{,}950 - \$157{,}851)}{\$157{,}851} = 7.53$$

Table 1: Cost Estimate for Single 6-ft Drilled Shaft

Description	Cost/unit	Unit	Units	Cost
Drill Shaft	$ 523.97	lnft	25	$ 13,099.25
Drilled Shaft Casing	$ 624.32	lnft	25	$ 15,608.00
Drilled Shaft Concrete	$ 379.12	cy	26.179939	$ 9,925.34
Column Concrete	$ 379.12	cy	20.943951	$ 7,940.27
Reinforcing Steel Total	$ 1.49	lb	19085.175	$ 28,436.91
Total Price =				$ 75,009.77

Table 2: Cost Estimate for Five 20-inch Driven CFT Piles

Description	Cost/Unit	Unit	Units	Cost
Pile Cutting Shoe	$ 196.10	ea	5	$ 980.50
Furnish Steel Pipe Pile	$ 83.54	lnft	45	$ 18,796.50
Drive Steel Pipe Pile	$ 10.00	lnft	25	$ 1,250.00
Pile Concrete	$ 379.12	cy	10.23	$ 3,877.09
Total Price =				$ 24,904.09