STRAAM Group - Bridge Pier Assessment and Monitoring Value added summary

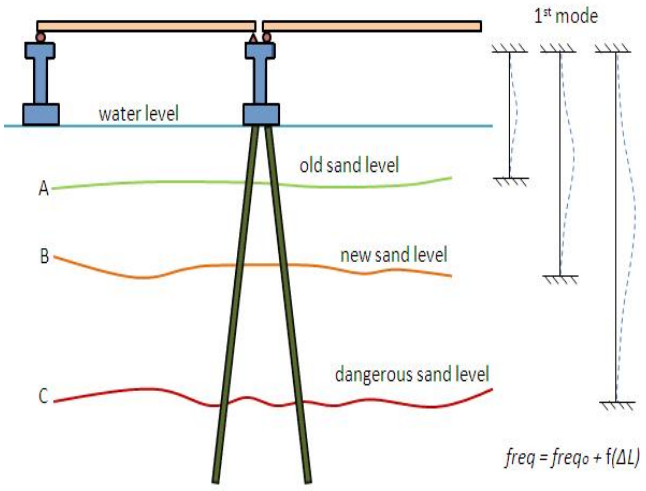
The information below describes one method for assessing and monitoring bridge piers which could be subject to a scour condition. Our goal here is to provide the owner with an understanding of the risk profile of the piers and provide the earliest warning if there is a change. This is just one approach and we focused on the following two areas:

1) **Baseline and Assessment** - Provide a baseline of the structure's dynamic response and use the dynamic information to calibrate a finite element model. This model helps identify the system properties. We identify modes of vibration which can be used as primary indicators of an advancing scour condition. Vertical response information can identify poor soil conditions under footings. We can compare future measurements to the baseline to quantify changes.

2) **Continuous monitoring** - Provide continuous dynamic information that will identify if the scour condition is affecting the piers. The change in response can track if the sand levels are getting lower; allowing the owner to anticipate that a problem is possibly developing before the structure has been damaged. We also measure tilt movements in real time to an accuracy of 0.0001degrees to show any progression of movement. This provides a continuous permanent record of the changes in response and actual movements.

To explain the assessment of scour conditions for this example, we offer the following:

Each bent can be viewed as a system where the piles are fixed in the sand at some depth (referred to as the point of fixity at the bottom, POF). The bent cap on top is somewhat fixed at the deck. Therefore the bent will bend between these two fixed points. This mode of vibration (referred to the first mode) will change with the length of the exposed piles to its POF. As sand is eroded, the length of the exposed pile will get longer thereby lowering the frequency of this mode of vibration.



This is one parameter we will use as an indicator regarding the performance of the structure. It gives a complete correlation of changes in the sand to the performance of the bent. Other performance measurements of the structure will also be part of the assessment.

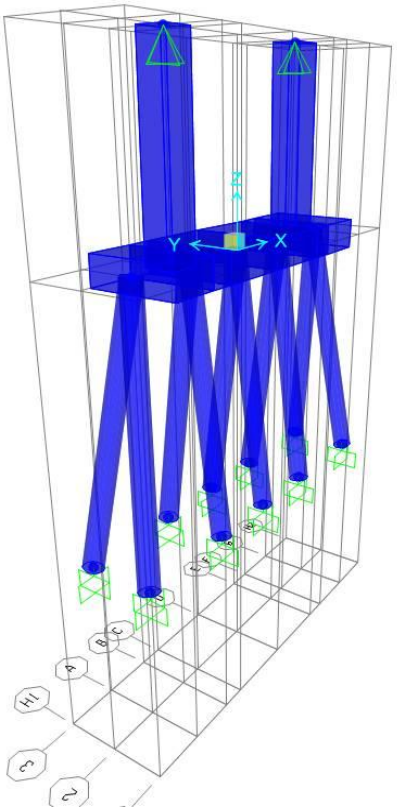


Figure 1 - Bent with 30' of piles to POF

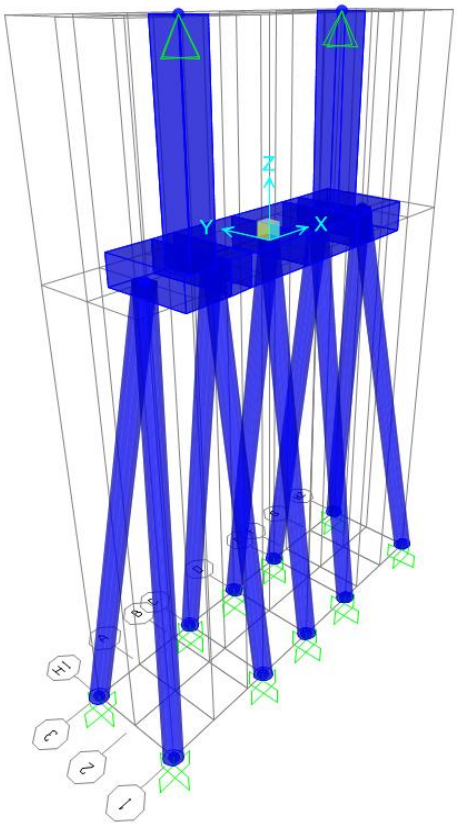


Figure 2 – Bent with 45' of piles to POF

We performed finite element modeling from plans of an actual pier which were used to help understand the system we would monitor. It allows us to anticipate how changes in the sand level will affect the response. The two diagrams represent a change in POF from 30' from the footing to 45' to the footing, or a loss of 15' of sand. This likely represents a 'good' condition and a 'dangerous' condition, respectively, assuming 60' piles.

The table below shows the predicted changes between the two scenarios in the model above for the first 3 modes of vibration; lateral bending (1st mode), longitudinal bending (2nd mode) and torsion (3rd mode). The variation in response is quite dramatic in these modes showing a change between 0.1 to 0.2 hertz for every foot of sand removed. A change of this magnitude will be easy to track in the real-time measurements.

Pile length	45'	30'		
Modal Frequency (Hz)			**% difference**	**Mode Shape**
1st mode	3.34	4.71	41.0%	lateral bending
2nd mode	4.83	7.24	49.9%	longitudinal bending
3rd mode	5.72	8.36	46.2%	torsion

Summary –

By taking baseline dynamic measurements on piers, owners can use this information to assess the performance of a structure. In this example, the task was to determine the depth of fixity of the piles, which for some bridges, can change due to scour. The dynamic response provides many other indicators regarding its performance and potential damage developing.

The value of this approach is to provide information to avoid very costly repairs. The baseline measurements can point out anomalies in the piers through varied response information in the X, Y and specifically the Z (vertical) direction. The vertical resonance information can be used to determine the spring constant of the soil thus highlighting poor conditions at the footing. Lateral modes can be used to determine performance characteristics including the point of fixity of the piles as described. Also, by comparing future measurements to past baseline measurements, changes that can indicate damage are quantified. When a system is installed for continuous dynamic monitoring a permanent record of all changes is created. But more importantly, it gives the most advanced warning on the progression of change that is available to the owner. This will provide advanced knowledge that a change in the risk of the structure is occurring. Changes in tilt of the piers validates that the structure is moving and is now experiencing damage. This comes well after changes in the dynamic response are seen and may represent a critical condition.

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Establishing Baseline signatures on structures can easily be incorporated into the inspection process. This can establish a data base of the structure's performance to avoid being blind-sided by dangerous conditions which may not be picked up during visual inspections. STRAAM Group is unique in our ability to collect and provide this information in real-time even when there is no traffic on the bridge.