HDR ONE COMPANY *Many Solutions*℠			Memo
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CC:	Michael Pochop		
Date:	5/26/09	Job No:	

RE: Ice Forces on Bridge Piers.

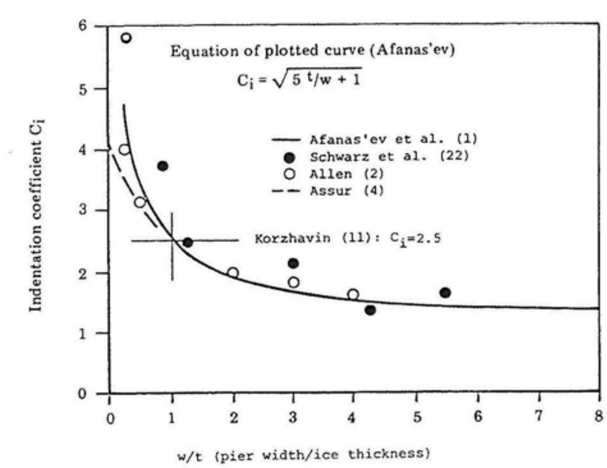
The indicated design of the supporting bridge pier will be a set of four battered piles encapsulated in a cylindrical caisson of 12 ft diameter. This caisson "shell" will extend from the pile cap to approximately 10 ft below the existing river bottom. With the exception of possible deep scour around the cylinder, the pier will appear hydraulically to be a vertical sided monopole to the flow.

Ice can fail against a structure in one of three modes, or a combination of the modes; crushing, bending, and buckling. For the purposes of horizontal loads on structures, generally, the controlling behavior is either crushing or bending. Failure by bending produces the lowest horizontal forces, but occurs only against slopes not more than 15° from the horizontal. However some benefit from bending failure is still attributed to slopes as steep as 75° from horizontal. The 1974 Canadian Standards Association applies empirical reductions based on slope angle, reducing the design horizontal load by a factor of 2 for a 45° slope. Other theories suggest that the 45° slope might reduce the horizontal load by a factor of ten.

For the case of the vertical monopile, the load is defined by the expression

$$F = cmk\sigma_c A$$

Where c is the indentation coefficient, which is a function of the ice thickness/pier diameter aspect ratio; m is the pier shape coefficient defined by the sharpness of the pier leading edge (= 0.28 for a vertical round edge); k is the contact factor (1.0 for perfect contact, and 0.6 for imperfect), and σ_c is the crushing strength of the ice, which is a function of the strain rate being applied, $\acute{\varepsilon} = V_{ice}/D_{pile}$, and of the ice temperature (at high strain rate, and colds temperature, σ_c becomes constant 400 psi). A is the projected contact area of the pier with the ice.



Two cases will be considered: flat sheet ice, and rubbled ice.

1) Assume flat ice 3 ft thick,
   c= 1.5, m = 0.28, k = 1.0, σ_c = 400 psi for major break up at cold temperatures.

   Then:
   F= (1.5)*(0.28)*(1.0)*(400*144)*(12*3) = 871 kips/ pile

2) Assume rubble ice, 12 ft thick,
   c=2.5, m=0.28, k=0.6, σ_c = 200 psi (melting temperatures but large pieces, internally sound)

   Then:
   F= (2.5)*(0.28)*(0.6)*(200*144)*(12*12) = 1,742 kips/monopole

   Note, this calculation assumes imperfect contact, but ignores probable voids in the rubble matrix, expected to be 35 – 40%. Reducing the total projected loading area by 40% reduces F to approximately 1,045 kips /pile.

REFERENCES

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