Crane Wind Loads with Particular Reference to Overturning

by
Jason Garber and Barry J. Vickery
Boundary Layer Wind Tunnel Laboratory

This paper summarizes a current study of wind loads on four typical container cranes in the operating configuration. The mean and fluctuating wind loads, as determined experimentally are compared with those obtained using the multiple frame data obtained by Georgiou and Vickery (1), as well as those calculated using various codes which usually deal with lattice structures in general. Overturning of cranes, first as rigid bodies and then as elastic structures, is addressed both experimentally and through numerical simulation. The objective is to provide a simple design criteria for the determination of overturning.

The overturning of cranes is being examined in two experimental programs. The first used rigid models of actual cranes which were placed in both smooth and turbulent flow. The testing was performed in Boundary Layer Wind Tunnel I at the University of Western Ontario.

The smooth flow tests were conducted near the inlet of the tunnel. The wind speed was slowly increased until overturning was observed. This was repeated for twelve directions per crane. The overturning moments of each crane could be measured directly (e.g., by applying static load) and then a smooth flow moment coefficient could be calculated. This could be compared to the coefficients predicted using the data mentioned above.

The test set-up for turbulent flow consisted of spires and carpet to simulate the turbulence and velocity profile appropriate for harbor cranes. The behavior was studied in two stages. The first was much like the smooth flow tests except that the mean speed was increased at three minute intervals until tipping occurred. A pitot tube mounted away from the model, at boom height, measured the mean speed for overturning. Where possible, a laser was used to record the displacements (i.e., rotations) of the crane during the test. In the second stage, the models were mounted on a force balance and mean and RMS shears and moments were measured. As well, time histories were taken for use in the numerical simulation.

The influence of the elasticity of the structure is currently being studied using a simplified "stick" model. Both the natural frequency and damping of the model can be varied. This model is being tested in turbulent flow with the effect of resonant vibrations on overturning observed. The objective is to test the current assumption that cranes essentially behave as rigid bodies when overturning (2), and to establish limits for when this assumption is no longer valid.

The question of gust duration for overturning has been addressed by Eden et al (3) by considering a mean applied moment with an added gust (constant speed) of sufficient duration to bring the crane to the point of instability. This study will make use of the measured time histories of base moment, along with a finite difference solution, to predict overturning of both rigid and elastic cranes.

To summarize, the goal of this paper is to compare overturning forces obtained experimentally with some of the existing empirical models. Once the forces are defined, they will be applied to the problem of overturning assuming both a rigid and elastic crane. In the end, a simple approach to the design of cranes for overturning will be presented. The experimental results are currently being compiled and will be presented in detail in the final paper.

References

1. Georgiou, P.N. & Vickery, B.J. "Wind Loads on Building Frames." Proceedings of the 5th International Conference on Wind Engineering, Fort Collins, 1979.

2. Kogan, J. "Crane Design: Theory and Calculations of Reliability." John Wiley and Sons, Inc., New York, 1976.

3. Eden, J.F., Iny, A. and Butler, A.J. "Cranes in Storm Winds." Engineering Structures, Vol. 3, pp175-180, July 1981.