Getting the wind up over crane designs

Are excessive wind forces being used for modern container crane design?...yes and no*

As a rule, the crane design industry ignores the dominant cause of wind damage. Microburst winds are seldom considered. Yet every year cranes are damaged or even destroyed by microbursts that suddenly hit cranes in operation.

Over the top?

But for the customary operating and stowed modes, wind forces are often overestimated by a large margin. Clearly this is important, since the crane manufacturer has to pay more for extra structure. And often the manufacturer is forced into extra design effort as well and more expensive construction details to avoid exceeding specified wheel loads.

Owners should care, too, because they have to provide stronger docks, stronger tie-down anchors and, year after year, they pay a small but measurable penalty for energy costs to operate the heavier structures.

Gantry cranes are subject to loads from many sources other than the lifted load. Many designers believe wind load is the most confusing and most unpredictable of the various design loads. There are several reasons for this.

- Data for maximum wind speeds are scanty. Site-specific data are virtually non-existent.
- Wind is turbulent and highly variable in four dimensions (time being the fourth). Thus at any given moment, the various surfaces of a structure are subject to completely different pressures. For design purposes, these varying pressures must be converted to equivalent static pressures with simplified variations over the height, depth and breadth of the structure.
- Wind drag of individual structural members is well-established by test data but little information exists for what happens to an entire assembly.

Lacking better data, crane designers must rely on engineering codes or proprietary wind tunnel tests. Until recently, neither option has produced very accurate results. Usually the loads are too conservative. But a heavier crane that is more safe for wind loads is less safe for dock loads, so what is regarded as conservative in one context may be risky in another.

Overestimates of wind loads may result in all sorts of grief when dock strength or tie-down capacity is marginal.

Out of bounds

Dissatisfied with the usual wind design criteria, Casper, Phillips & Associates (CP&A) has, from time to time, enlisted the services of the University of Western Ontario's wind testing facility. UWO has the number one rating for wind engineering expertise for buildings, bridges and similar structures.

It uses a unique type of wind tunnel known as a boundary layer wind tunnel (BLT). This tunnel is quite distinct from the more common aeronautical wind tunnel which, as the name implies, is used for airplane testing.

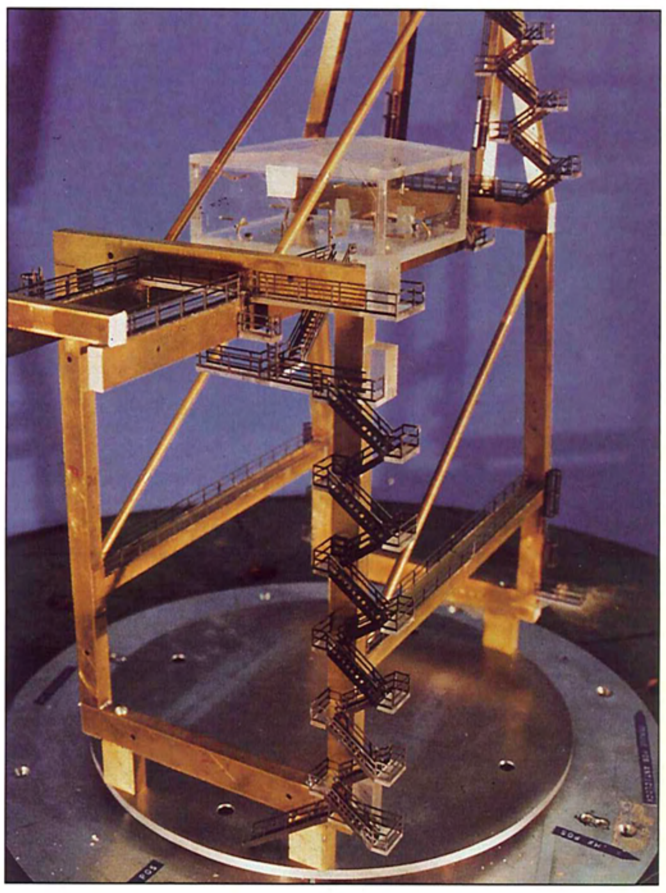
Aeronautical tunnels have a uniform speed air flow over the entire length, height and width of a tunnel. A BLT has features which deliberately create turbulent air flow from the surrounding terrain to simulate actual wind as experienced by the real structure. Even the effect of nearby buildings and other site conditions can be introduced if desired.

In other words, the air flow in an aeronautical wind tunnel is one-dimensional. In a BLT it is four-dimensional. That difference is vital for accurate determination of wind crane loads.

On earlier tests CP&A obtained data for global wind forces and moments for the crane as a whole. These data were of limited use because they did not define how the loads are distributed throughout the structure.

Taichung tests

Recently more elaborate tests were conducted to measure instantaneous wind pressures on individual members, using a 1:100 scale model (viz: 30 cm on the model for 30m on the real crane)



This shot of the model on the turntable shows the pressure taps (black holes). Instantaneous pressures are measured at each tap and the data are relayed via internal wires to a data log PC

Figure 1: 20 m/sec stowed wind speed: wind direction parallel to gantry rails. TG stands for trolley girder (Source: Casper, Phillips & Associates)

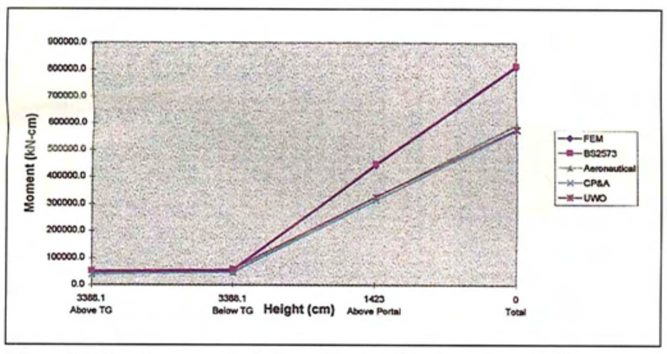


Figure 2: 20 m/sec stowed wind speed: wind direction perpendicular to gantry rails. (Source: Ibid)

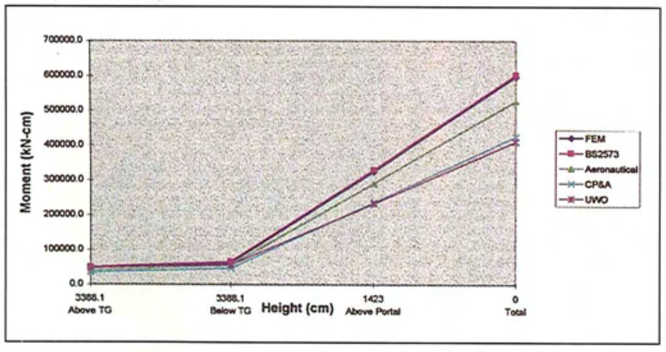


Figure 3: 70 m/sec operating wind speed: wind direction parallel to gantry rails. (Source: Ibid)

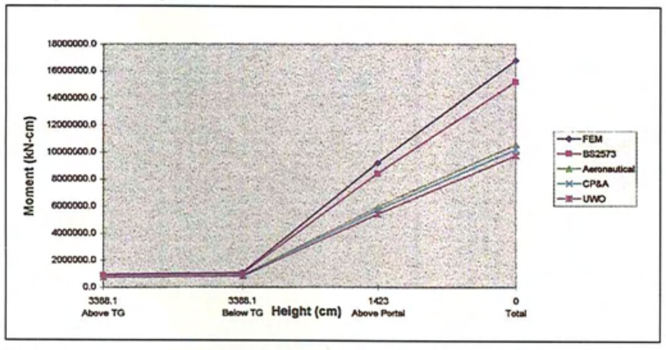
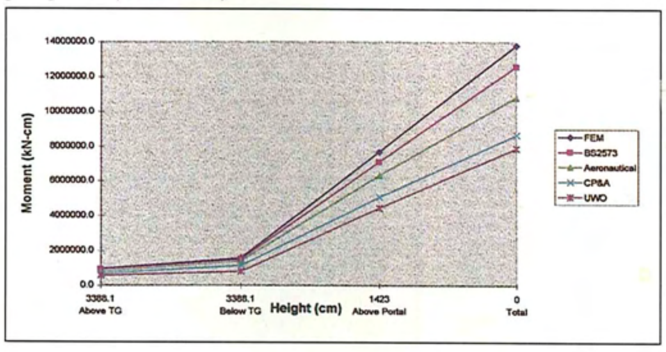


Figure 4: 70 m/sec operating wind speed: wind direction perpendicular to gantry rails. (Source: Ibid)



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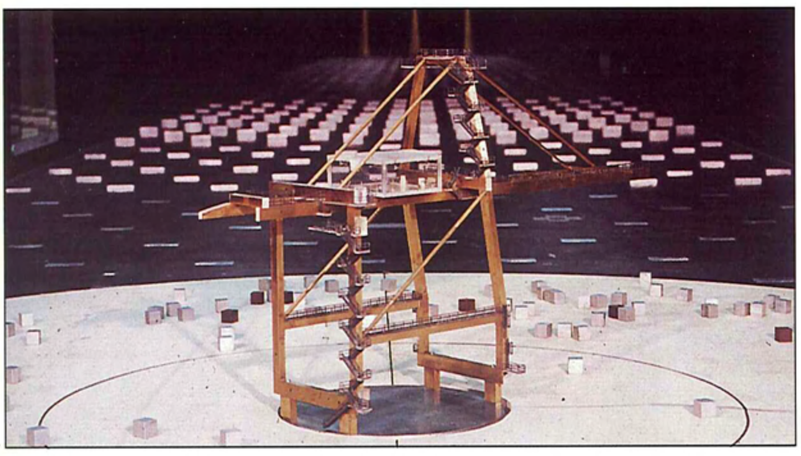

General view of model on turntable. In the background are ground surface features that create height and gust effects that simulate real wind effects. These features distinguish BLTs from an aeronautical type tunnel, says CP&A

of a 35 tonne container crane being designed by Ederer for the Port of Taichung. Test highlights were:

- Boom up and down models were rotated at 10 deg intervals from 0 deg to 180 deg (19 azimuths).
- A total of 250 pressure taps were sampled 400 times/sec for a 250 sec duration. This is the full scale equivalent of about 15 measurements/sec for one hour.
- Generic site conditions of open water and flat, open terrain. This is slightly conservative as it ignores common protective features of the harbour and nearby terrain such as breakwaters, buildings, trees and hills. Thus the test data can be safely used anywhere without regard to actual site conditions.

CP&A fed UWO's four-dimensional raw test data into a computer and manipulated the enormous volume of data to develop useful design loads. The results are depicted in the figures on the previous page.

These figures also show comparisons with loads calculated from FEM, BS 2573 and JIS wind design factors. The operating wind speed of 20m/sec (45 mph) is fairly typical everywhere and has nothing to do with location in windy areas. It has to do with the design wind load applied concurrently with other operating loads. It could be used as the wind speed at which the crane should be taken out of service, although usually operations cease at a slower speed and the crew proceeds to park and stow the crane.

The 70m/sec (157 mph) stowed wind speed is typical of a severe typhoon region. In our case, Taiwan is the location but it could have been Guam, Puerto Rico or anywhere else subject to typhoon or hurricane wind forces.

Parallel and same lines

The graph plots show that there is not much new information for wind direction parallel to the boom. Tests made over 20 years ago in aeronautical type wind tunnels gave design data similar to the most recent tests. These earlier tests also demonstrated the conservatism of engineering codes such as FEM and BS 2573.

When wind perpendicular to the boom is considered, our recent tests show that previous tests overestimated the magnitude of actual wind loads.

These was no need for pressure tap data on earlier tests because air speed was constant over the full height of the model. Now we have proprietary data for wind pressure distribution throughout the crane for simulated real winds. These are new data. As indicated above, they were collected for 19 different wind directions as the model was rotated on the turntable.

The plotted points on the far left of each figure are summations for the upper works components. The second set of points are summations for all components above the underside of the trolley girder including the boom. Third are the summation for components above the portal and fourth set are for the entire crane.

In summary the figures show that CP&A's simplified design factors come very close to the UWO test data, and loading obtained from applicable design codes are "over conservative" by a considerable margin.

This may or may not be important, depending on design wind speed, dock strength and stability requirements. They show that it may be viable to justify smaller design loads when wind load is causing difficulty in the design phase. ❑

Flame is the spur

A reader in Costa Rica, Carlos Alvarado from Japdeva Port Authority's heavy duty equipment workshop, wrote asking for more information on the Cristobal crane accident investigated by CP&A as reported in the April 1996 edition of *WorldCargo News* (p28). CP&A, meanwhile, has provided more data on the repairs.

Local resources were limited. No cranes were available and tools and materials were also difficult to obtain. But the port's own workforce provided able assistance to the repair specialists brought in by CP&A.

One suggestion was to take down the buckled strut and either repair it or replace it with a new one. But this was not practical because all the upper works members, including A-frames and backreach truss, are pin-connected. If the compression strut were temporarily removed, the remaining linkage would collapse.

In situ repair, using flame bending (ie thermal upset) techniques, was a better choice because:

- It could be done without a crane
- The original geometry could be preserved without needing to know in advance the as-built length of the original strut
- Time and cost of bracing the unstable linkage were avoided
- The special rigging could be erected by the port's workforce.

This case is probably the most severe example of buckling that has ever been flame straightened, says CP&A. Its repair expert, Dan Holt, was not at first fully confident that it could be done, particularly if the severity of the crimping had cracked the steel plates. This turned out to be the case and it greatly complicated the repair.

Crack stopper holes were drilled to keep the cracks from running out of control. These cracks were repeatedly welded and then recracked as the crimps were pulled out.

Once the plates were restored to a flat shape, the cracks were permanently rewelded and NDT-inspected by UT and MT. Holes were covered with steel straps which were seal-welded to preserve the original airtight corrosion proofing. ❑