Pilot Reported Roughness: Roughness Investigation and Repair

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Early in 2011, the Greater Toronto Airport Authority (GTAA) resurfaced Runway 05-23 at Toronto's Lester B. Pearson International Airport (YYZ). Not long after opening the runway, Air Canada began getting pilot complaints of runway roughness when operating from Runway 05-23. The aircraft's Flight Data Monitors began registering excessive loads (1.70g) at the center of gravity of their 777 aircraft in response to roughness at the intersection of Runway 15R. APR was asked to investigate and identify the area of roughness, and to assist the GTAA in developing a repair that would eliminate the bump without compromising needed watershed performance for Runway 15R. Figure 1 illustrates two plots: one of the runway's profile before the overlay and one of the changes created by the overlay. Figure 2 illustrates the aircraft's response to the measured profile in the vicinity of the Runway 15R intersection. Accelerations near 1.0g for this simulation, well over the +/-.40g threshold. Please note the undulations (multiple event roughness) on either side of the 15R intersection.

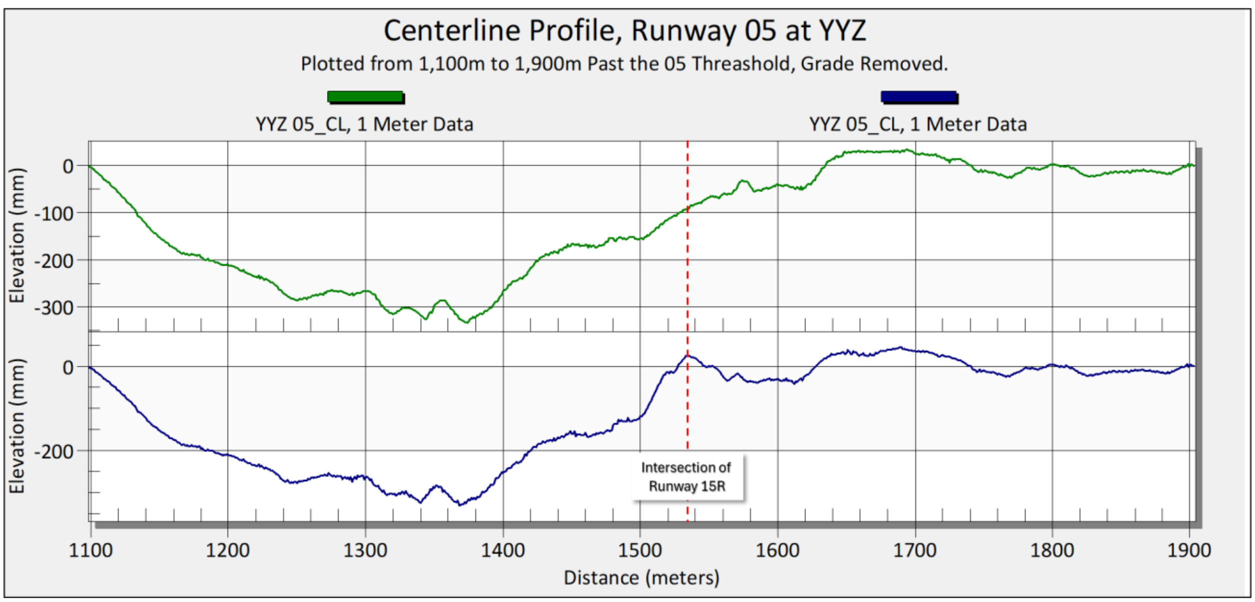

Figure 1. The measured runway profile of Runway 05-23 before overlay (top) versus after the overlay (bottom).

A traditional survey crew measured the affected area of the runway. APR used that profile data to conduct a variety of takeoff and constant speed taxi simulations to help identify the roughness events. Because the intersection of 15R is located near the midpoint of 05-23, this roughness will affect takeoff operations in both runway directions, 05 and 23. What APR's analysis found is that the aircraft did not respond to just one event, the intersection with 15R, but was responding to a series of events that led up to the 15R intersection. The bumps and dips preceding the intersection caused the aircraft to "rebound" from those events as it encountered the up side of the 15R intersection. Figure 2 illustrates the measured profile of the affected area as measured in 2007 (top) and the new profile, measured after the 2011 overlay. Note the difference in pavement profile located around the 1,540-meter mark.

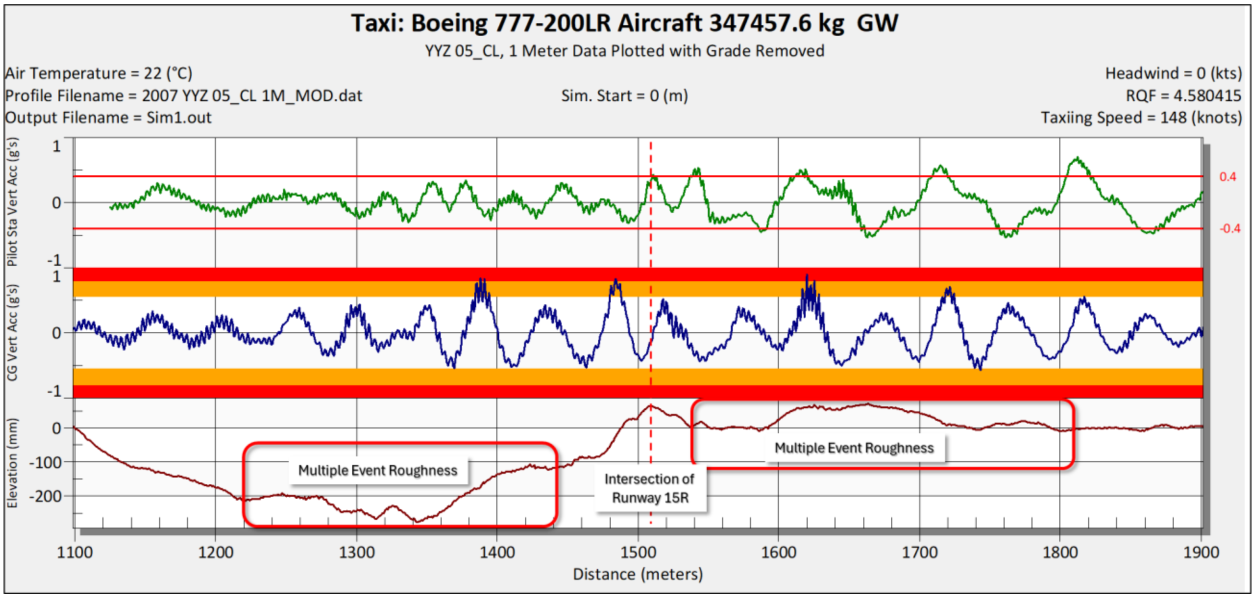

Figure 2. Aircraft simulation of a 777-200 encountering the intersection of Runway 15R.

Once the bump locations were identified, APR began an iterative process of making straight line repairs to the measured profile. This process involved making conservative modifications (analytically) to the profile, then simulate an operation, in this case, a high-speed taxi using a model of a Boeing 777-200. This process is repeated until the desired ride quality is achieved. Figure 3 illustrates the notional changes to the runway's profile (bottom of plot) versus the original profile (top). Once the optimum repair was designed, the repair profile was provided to the GTAA for use by their paving contractor. APR's simulations indicate that the repaired profile yields a dramatic improvement in ride quality for the 777 aircraft. As Figure 4 shows, the aircraft's accelerations are well within the .40g threshold of acceptability.

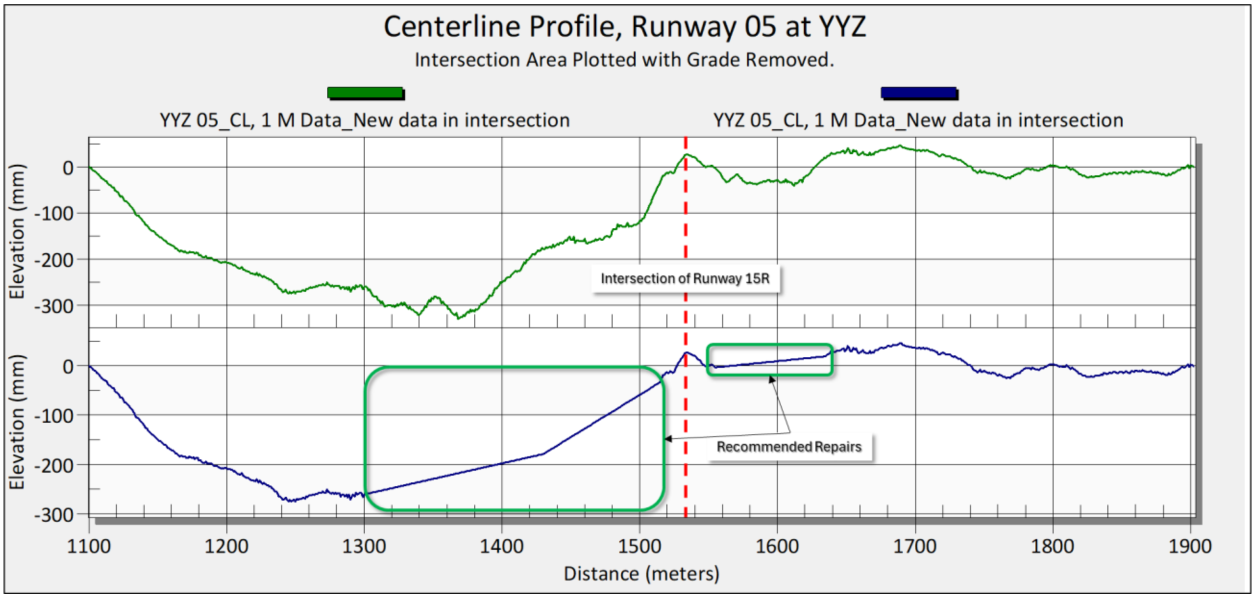

Figure 3. The profile of Runway 05-23 after the 2011 overlay (top) versus the proposed repair designed by APR (bottom).

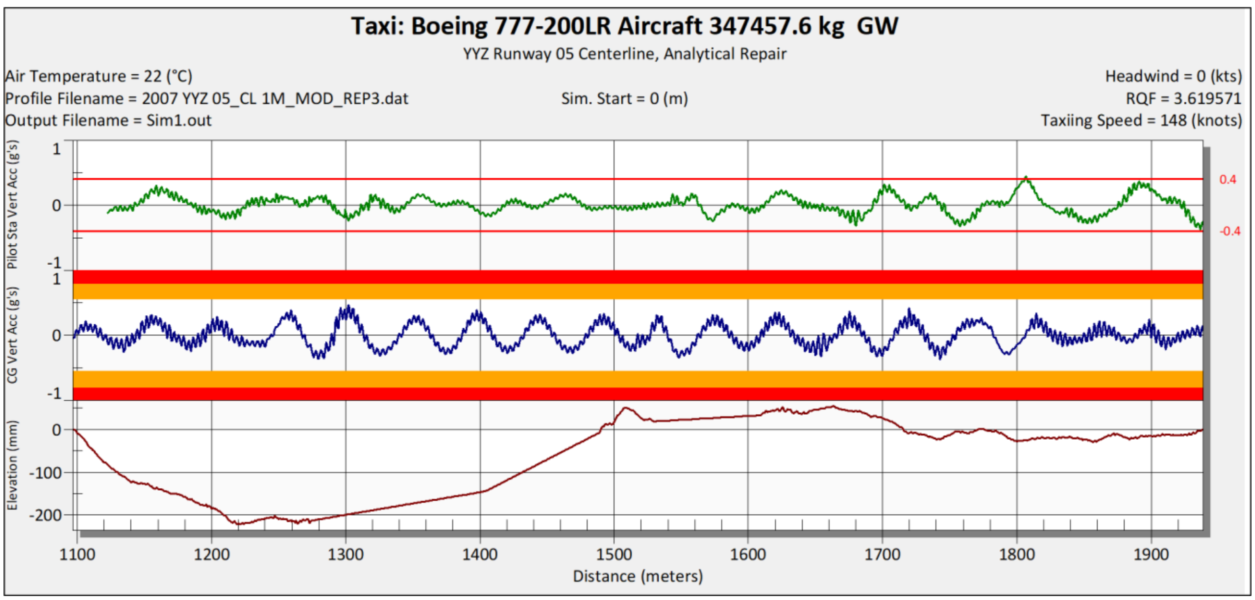

Figure 4. Aircraft simulation of a 777-200 performing a constant-speed taxi over the *repaired* profile with dramatically improved results.

It makes sense to evaluate a runway design anytime an intersection is involved, or if it is necessary to tie into existing elevations with vertical curves. It is a cost-effective method to ensure that the intended profile does not create a ride quality problem. This analysis could prevent unnecessary corrective action and added expense.

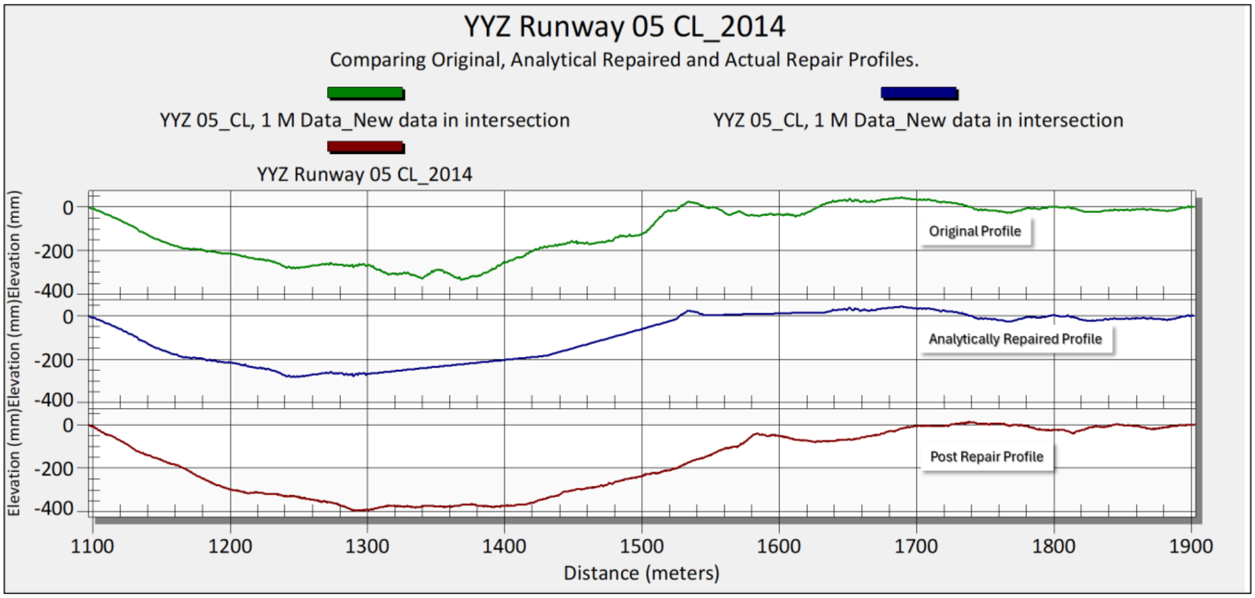

Figure 5. The original 2011 overlay profile (top) compared to APR's engineered design (middle) and the as-built repair (bottom).

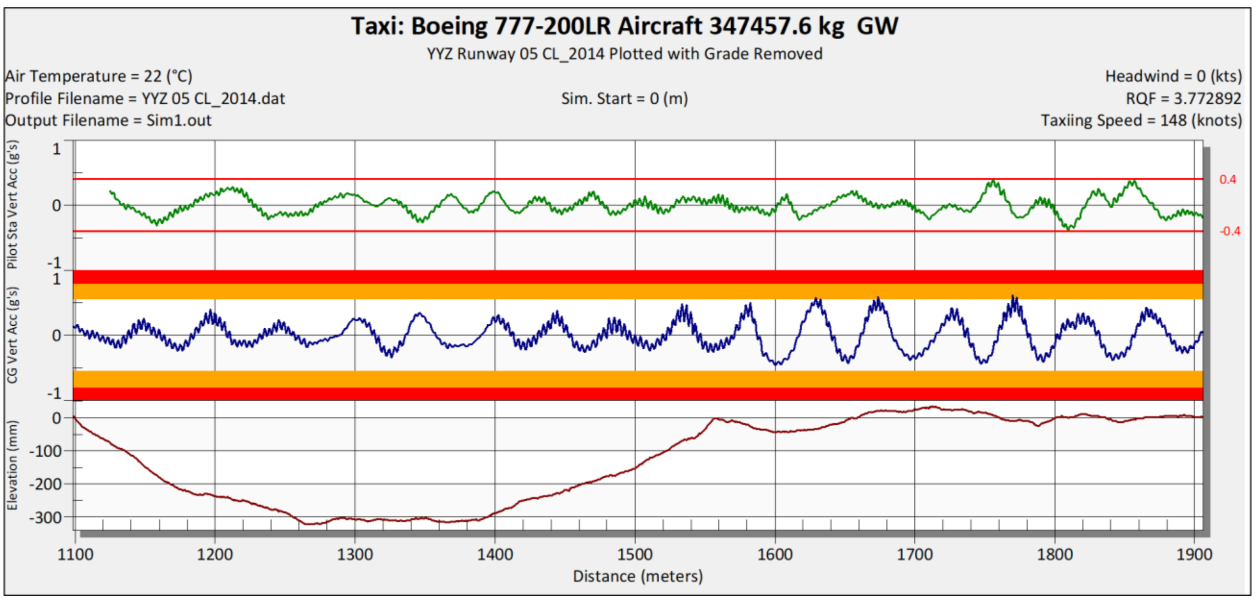

Figure 6. Aircraft simulation predicts significantly improved ride quality for the newly repaired profile.

Later in 2014, APR was asked to re-assess Runway 05-23 to update the pavement management program at YYZ. Using the Auto Rod and Level, three lines of survey were measured of this runway. Figure 5 plots the post repair profile of the affected area compared to the original problematic profile and the analytical repair APR provided to the GTAA. When assessing the ride quality of the actual repair, the ride quality improved significantly, eliminating pilot complaints (Figure 6).

Evaluating a runway design anytime an intersection is involved or if it is necessary to tie into existing elevations with vertical curves is a cost-effective way to ensure the end result produces acceptable aircraft responses and does not produce complaints of roughness. This analysis could prevent unnecessary corrective action and added expense.