Finding the Best Way to Evaluate Runway Roughness

By Michael Gerardi

I had a frustrating experience the other day. I was performing some routine maintenance on my car and I needed a specific sized wrench for a bolt I needed to remove. Not being good at guessing what size, it took me four trips to my tool box before I grabbed the right sized wrench. That was wasted time and energy that I could have used to fix the problem. In your work on airfield pavements have you ever wasted your time and money using the wrong tool trying to diagnose or fix a problem such as runway roughness? Unfortunately, there are many organizations out there today that grab the "wrong tool for the job" and try to make it work. Most of the time, they grab the wrong tool because they believe it's the only one available. I hope this article helps professionals like you realize that today, there is a much better tool to use.

What's in your toolbox?

Any airport that has a roughness problem wants to get the problem fixed. Airports often find out about roughness problems through pilot complaints. However, by that time two things are already occurring. First, excessive dynamic loads are being experienced by the pavements as the aircraft rebound from the pavement roughness. Secondly, excessive accelerations are being experienced by the operating aircraft that lead to fatigue damage on aircraft structure. To solve this issue an airport may turn to the Boeing Bump Index (BBI). But, as discussed in APR's article *"Boeing Bump Index – Additional Methodologies Recommended"*, this tool is pretty limited. Because BBI is an index, it can fail to accurately characterize the severity of the roughness. Additionally, the BBI can only evaluate single events. Most areas of pavement roughness that produce pilot reports are multiple events; that is many bumps and dips in succession – something the BBI will miss.

Another common tool used to evaluate roughness is the International Roughness Index (IRI). IRI is quickly becoming the standard method to evaluate the ride quality for roads and highways, but it is not designed to evaluate the ride quality of a runway. If you're not familiar with it, IRI is a mathematical representation of a car's suspension system. Specifically, it's the representation of one-quarter of a car – one wheel and its suspension system. This algorithm then evaluates the measured profile data of the pavement using that quarter-car model. It computes the vertical translation of the suspension system in relation to the profile data. The problem with this is it's the model of a car, not an airplane. This single tire / suspension model will respond to much shorter wavelengths than will a commercial aircraft. Secondly, like BBI, IRI is also an index. Indexes can mischaracterize the severity of a roughness event due to the event's location along the runway.

IRI is designed to predict the response of the vehicle at a constant speed; 35 mph (56 kph). Now, consider a commercial aircraft performing a takeoff operation. The speed certainly isn't constant. An aircraft accelerates through rotation and becomes airborne. As the aircraft accelerates, the pavement's wavelength of interest becomes longer. Yes, the aircraft can still respond to shorter wavelength bumps and dips during takeoff, but now it will also respond to longer wavelength events as well and the wavelength will continue to grow until rotation is achieved.

Not accounting for speed variability is the primary reason why indexes such as BBI and IRI fail to properly identify a roughness problem.

So, what is the alternative?

Considering that the aircraft's speed is variable, what is the best method to not only identify the location of the roughness, but to also quantify the effect roughness has on the aircraft, its occupants and the pavement? APR's customers believe aircraft simulation is the best method. Aircraft simulation is the only method that takes the *aircraft* into account when assessing pavement roughness. After all, isn't that what matters here?

To help illustrate this point consider the plot shown in Figure 1. This is a typical aircraft simulation plot predicting the accelerations of a Boeing 737-800 performing a takeoff. The upper trace plots the predicted responses (in accelerations) at the pilot's station. The center trace is the predicted accelerations at the aircraft's center of gravity, and the trace along the bottom is the plotted pavement profile. The upper and middle traces are banded by red lines. These red lines denote .40g in vertical acceleration. While there is currently no threshold declaring what is too rough for airfield pavements, .40g seems to be a good unofficial threshold and is backed up with two studies. Boeing conducted a study and found that .40g is the point where fatigue damage begins to occur on aircraft structure such as landing gear components[1]. Another study found that .40g is the point where humans begin to feel discomfort[2].

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[1] DeBoard, K.J. and E.L. Gervais. "Runway Roughness Measurement, Quantification and Application – The Boeing Method." Document No D6-81746

[2] Goldman, D. E. and H.E. Von Gierke. Effects of Shock and Vibration on Man *Volume III of the Shock and Vibration Handbook, Chapter 44, 1961*.

Looking at the pavement profile in Figure 1 you can see an area of multiple event roughness that consists of short wavelength, small amplitude undulations (red box). The predicted response at the cockpit and center of gravity (CG) slightly exceed the .40g bands indicating that it is mildly rough, but overall not too bad.

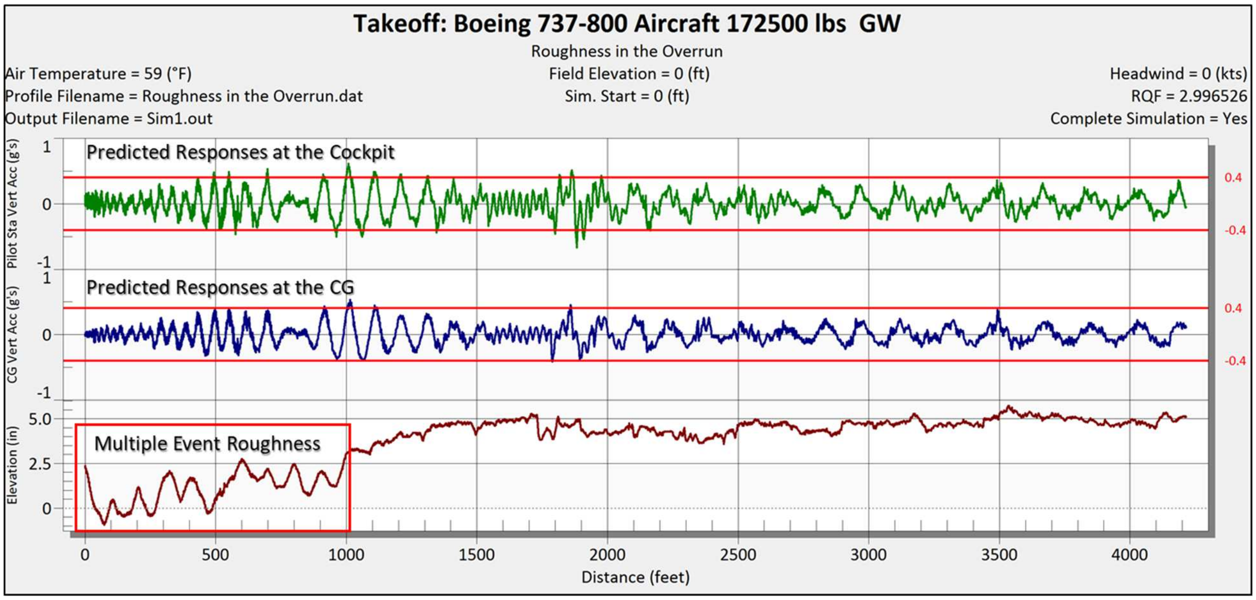

Figure 1. Takeoff simulation of a 737-800 on a runway with multiple event roughness.

To illustrate the importance of its location along the runway, the profile data containing the roughness was copied and placed 2,000 feet (610 meters) down the runway. At this location the aircraft will be traveling much faster which has a significant effect on the aircraft's response to the pavement roughness, as seen in Figure 2.

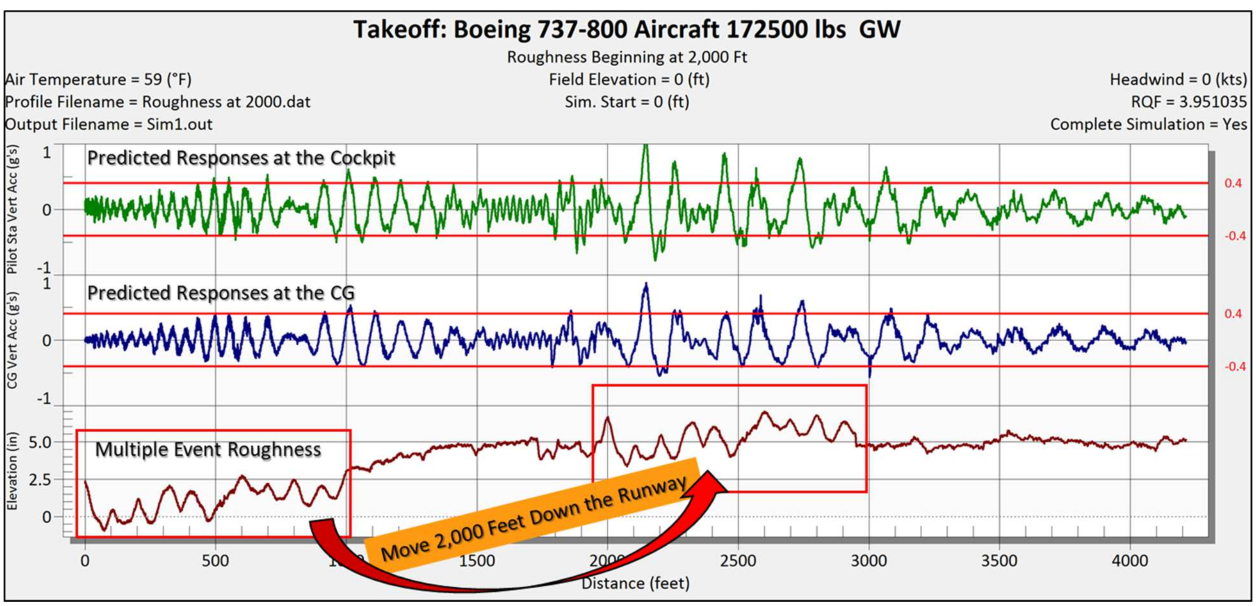

Figure 2. Moving the area of roughness 2,000 feet (610m) down the runway makes a significant difference.

Responses at the cockpit and CG are now considered significant and will most likely result in pilot and passenger complaints. Furthermore, the additional dynamic loading can accelerate pavement failure localized to that area and finally, fatigue damage to aircraft structure will occur when exposed to this level of loading.

So, if you agree that indexes such as BBI and IRI can mischaracterize roughness events based on their location along a runway, I would ask you to consider aircraft simulation to identify and quantify any roughness you may have. After all, wouldn't you rather grab the right tool the first time?

If you would like to learn more, please contact me at mag@aprconsultants.com