

# Temporary Construction of Ramps and Their Effect on Dynamic Aircraft Response

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# Necessity of Temporary Construction Ramps



- In Certain Situations Runways Must Remain Open While Being Reconstructed.
  - Temporary Ramps are Required before Runway Opens in Morning
    - Almost Exclusively Asphalt
  - New Method to use Accelerated Type III Portland Cement or Belitic Calcium Sulfoaluminate Rapid Set Concrete
  - Slab Height and Ramping is the Challenge

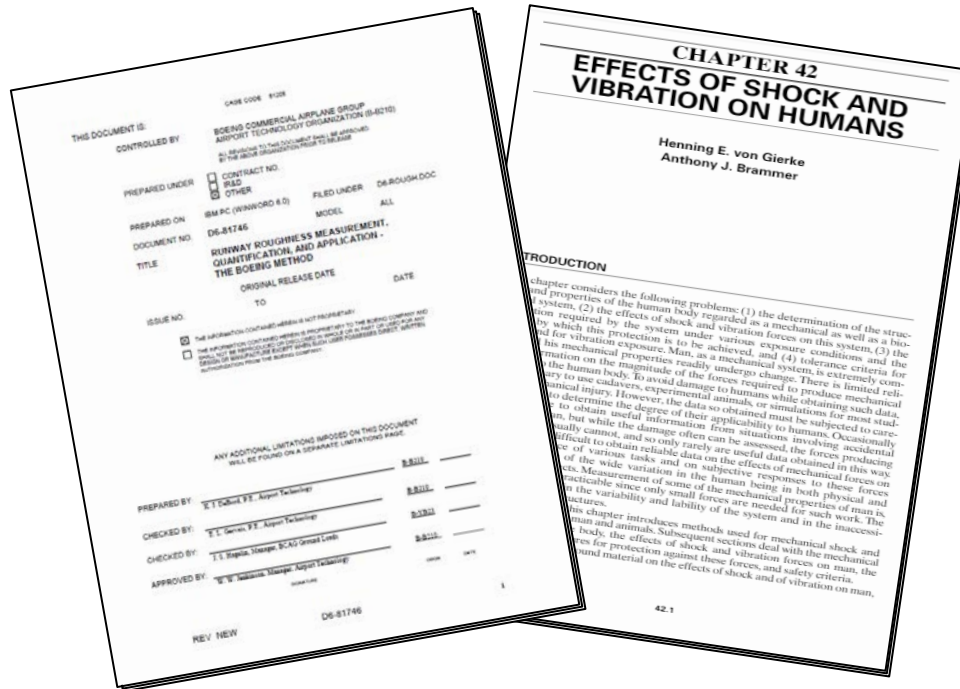
# Temporary Ramps and Ride Quality

- The Rapid-Set PCC Overlay Could Require a Constant Thickness of Six Inches.
  - Questions Arose about the Affect of a Ramp of Six Inches on Aircraft Dynamic Loads
    - What is the Effect of a Short, Steep Ramp Vs. Longer, Shallower Ramp?
      - Is Aircraft Response Significantly Different?
    - What are The Limits of Acceptable Aircraft Ride Quality?
    - What Affect Will the Surrounding Pavement Profile Have on the Aircraft Response – Will the Ramp Compound the Problem?

# Methods of Analysis Available

- Aircraft Simulation
  - Predicts how the Aircraft Will Respond to the Ramp and other Profile Characteristics of the Runway
- Boeing Bump Index
  - Evaluates Event Amplitude Vs. Wavelength for Single Event Roughness
- FAA AC 150/5380-9 Guidelines and Procedures for Measuring Airfield Pavement Roughness
  - Temporary Ramps Not-To-Exceed Three Inches by 40 Feet in Length (.57% Grade)

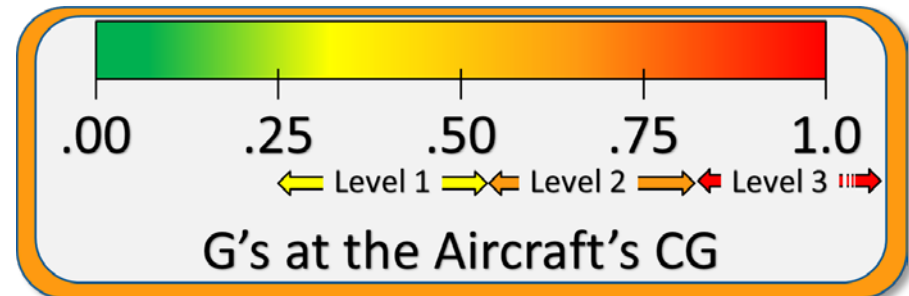
# Thresholds of Acceptability



- .40G in Vertical Response is an Unofficial Threshold of Acceptability
  - Boeing Study on Structural Fatigue
    - Boeing Report D6-81746
  - Shock and Vibration and Human Discomfort
    - Shock and Vibration Handbook, Chapter 44 “Effects of Shock and Vibration on Man” by D. E. Goldman and H. E. Von Gierke

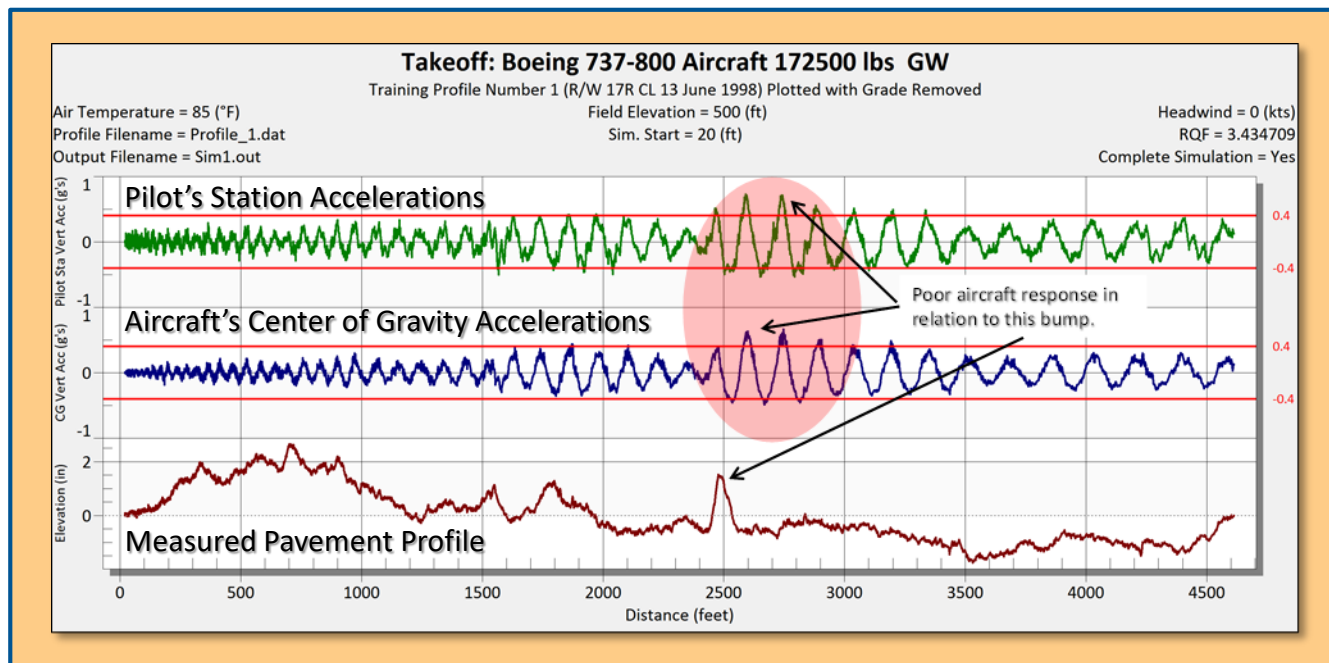
# Boeing's Levels of Roughness Based on Accelerations at the Aircraft's CG

- Level 1 Roughness
  - .25G to .54G
  - **Acceptable**
- Level 2 Roughness
  - .55G to .79G
  - **Excessive**
- Level 3 Roughness
  - .80G and Up
  - **Unacceptable**

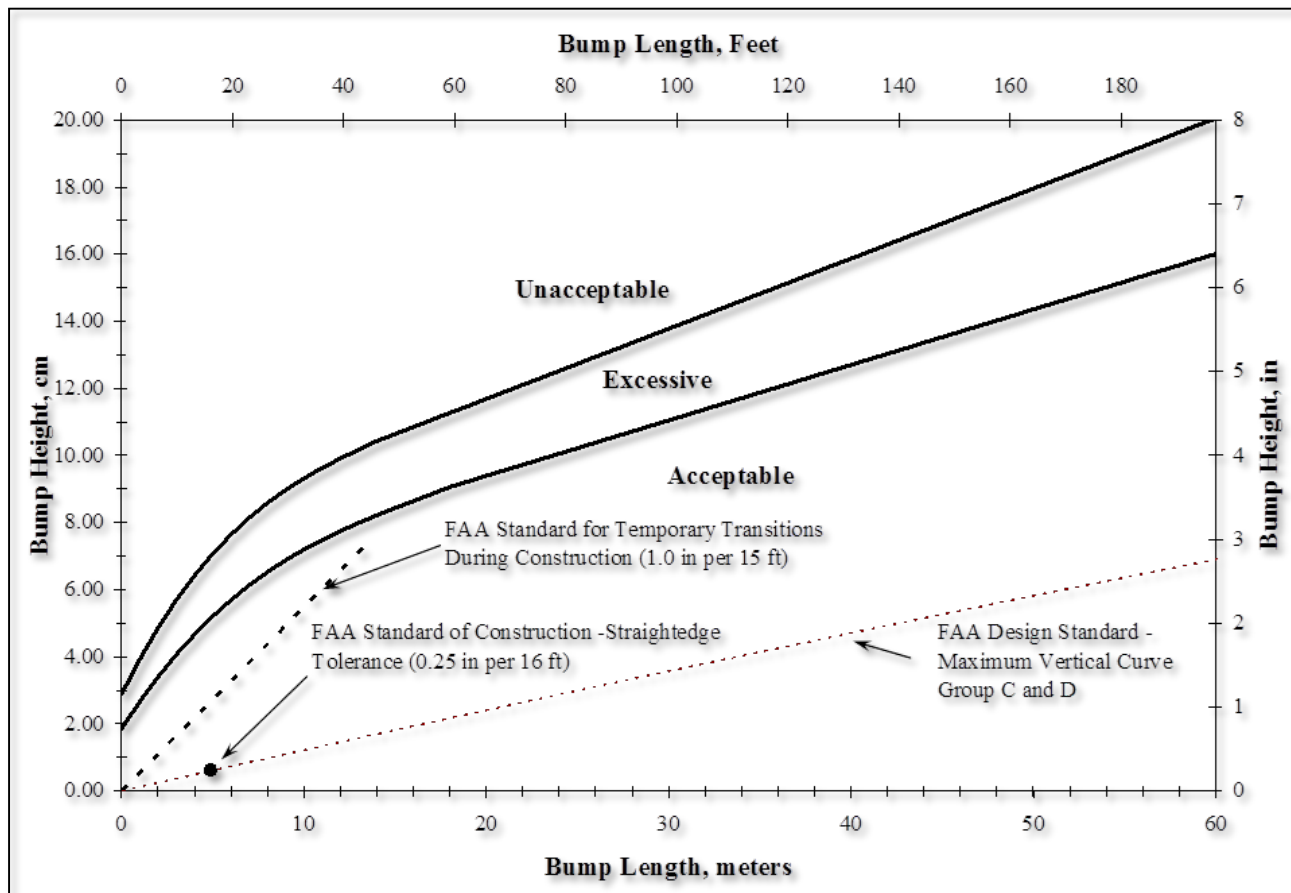


# How to Determine an Aircraft's Dynamic Response

- Aircraft Simulation was Used to Determine Aircraft Response to Proposed Ramp Designs



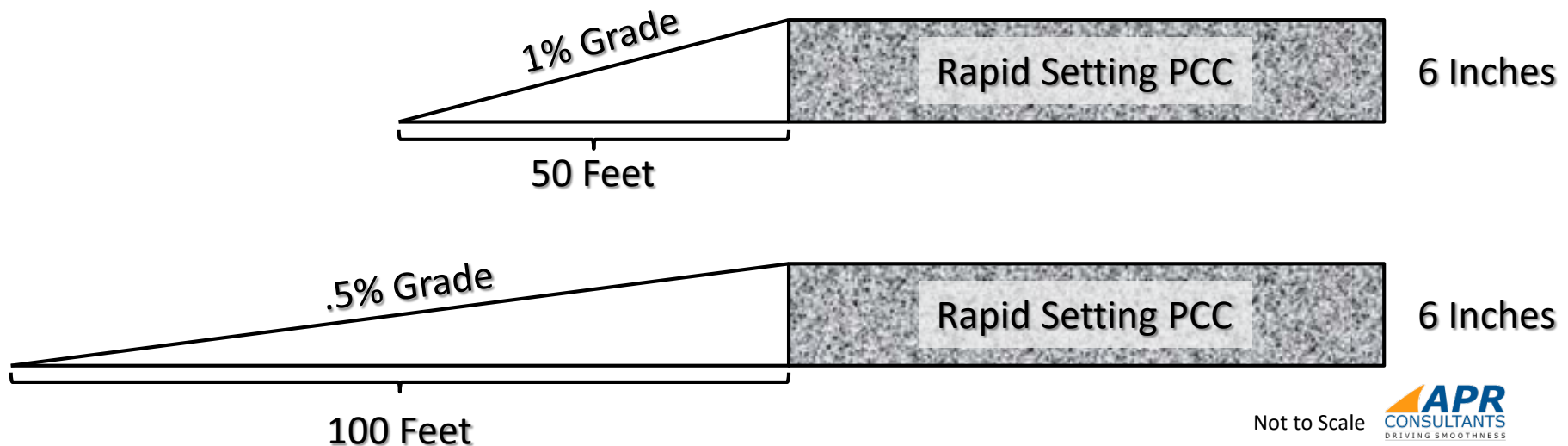
# BBI and AC 150/5380-9





# Ramps Studied

- Two Six-Inch Ramp Types were Considered:
  - 1% Grade That is 50 Feet in Length
  - .5% Grade That is 100 Feet in Length



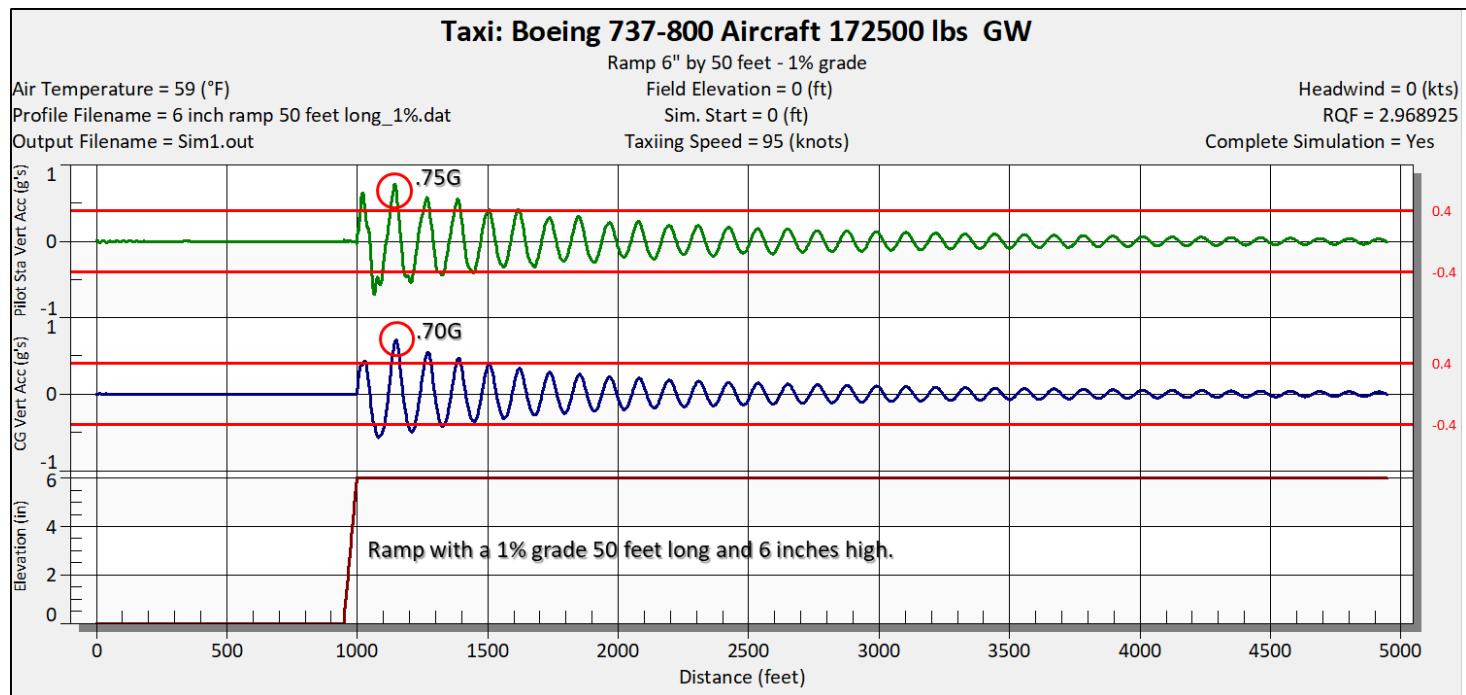
# How Do Aircraft Respond to These Ramps?

- The Original Question for this Study was; *“What Affect Would These Ramps have on Aircraft Dynamic Response?”*
  - Two Artificial Runway Profiles Were Created
    - Perfectly Flat Runway Except for Ramp
    - Runway One was a 50-Foot Long Ramp Six Inches High Requiring a Grade of 1%
    - Runway Two was a 100-Foot Long Ramp Six Inches High Requiring a Grade of .5%
  - The Ramps Were Located 1,000 Feet into a 5,000-Foot Runway

# How Do These Ramps Affect Aircraft Response? (Con't)

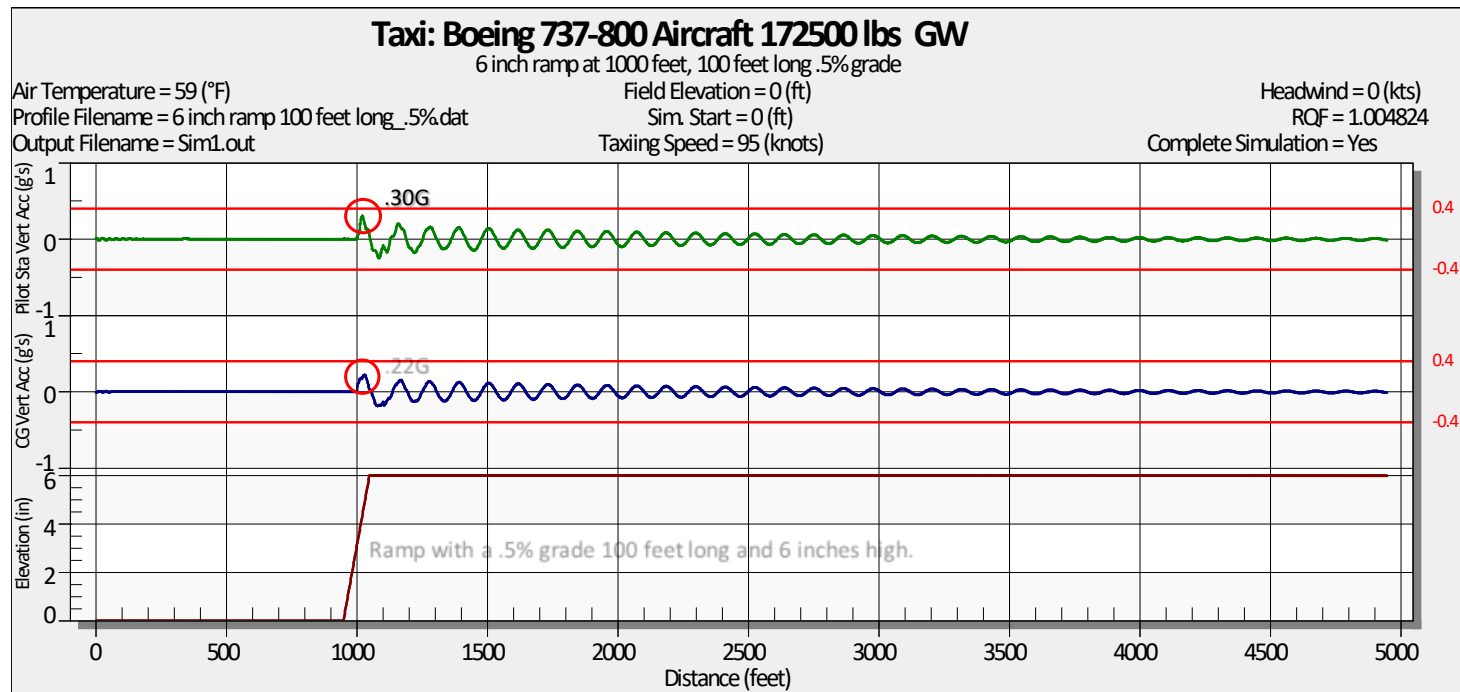
- Aircraft Simulation was Used to Determine Aircraft Response
  - A 95-Knot Constant-Speed Taxi using Boeing 737-800 Was Conducted on Each Ramp
  - Comprehensive Mathematical Aircraft Models
    - Lift / Drag / Thrust
    - Non-Linear Gear Characteristics
    - Flexible Aircraft Structure
    - Roll-Degree of Freedom
    - Maximum Takeoff Gross Weight
    - Air Density Altitude

# Ramp 1, 50-Foot Long 1% Grade



Level 2 Responses are Predicted

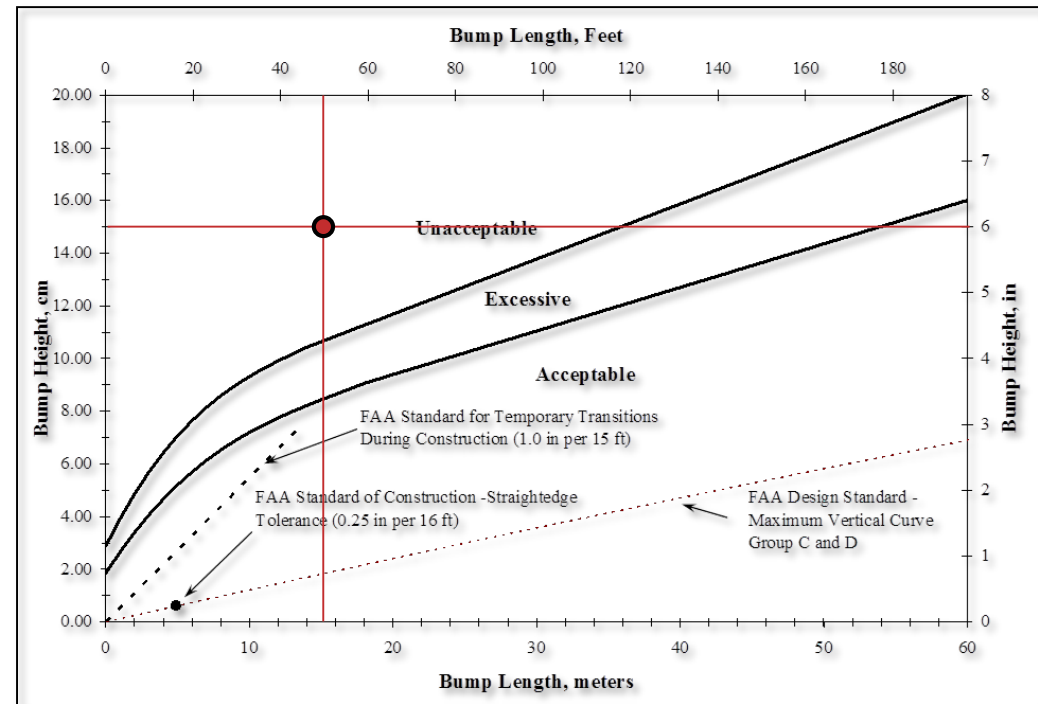
# Ramp 2, 100-Foot Long .5% Grade



Acceptable Responses are Predicted

# Boeing Criteria

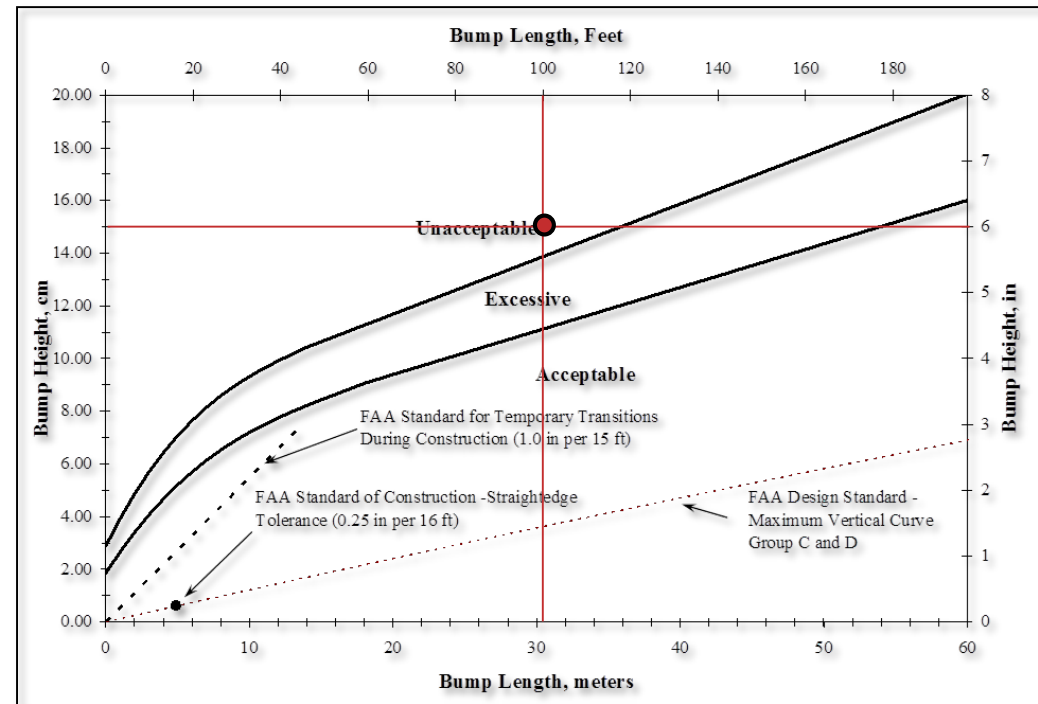
- **Acceptable** – Minor impact on aircraft fatigue damage and minimal passenger discomfort
- **Excessive** – Pavement repair recommended. Immediate closure not required
- **Unacceptable** – Immediate closure of the affected pavement



**Ramp 1, 50-Foot Ramp by Six Inches in Height**

# Boeing Criteria

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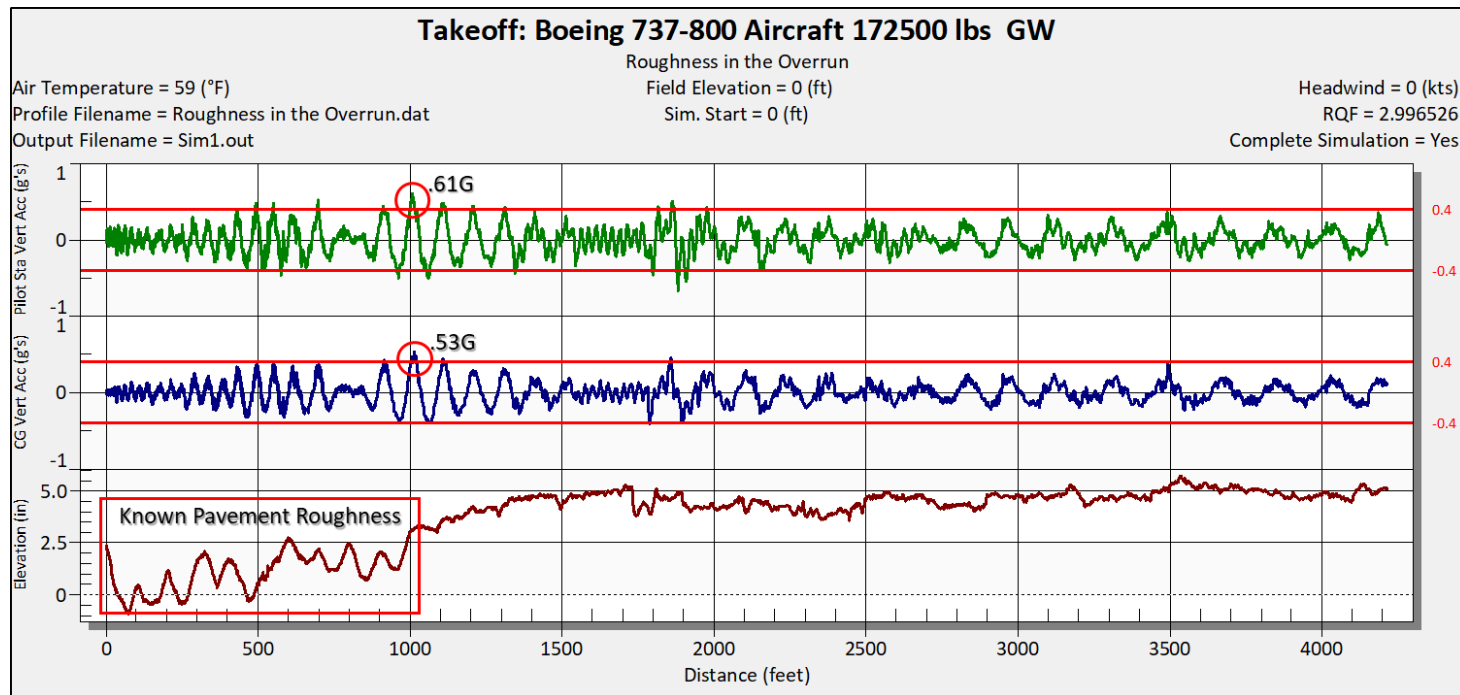
**Ramp 2, 100-Foot Ramp by Six Inches in Height**

# Same Ramps on “Real World” Runways

- In an Effort to Make this Study Consistent with Real-World Scenarios, A Variety of Situations Were Investigated
  - Ramps Inserted into Areas of Known Pavement Roughness
  - Ramp at Various Locations on an “Average” Runway
    - Encountered with A Boeing 737
    - Encountered with A Boeing 777

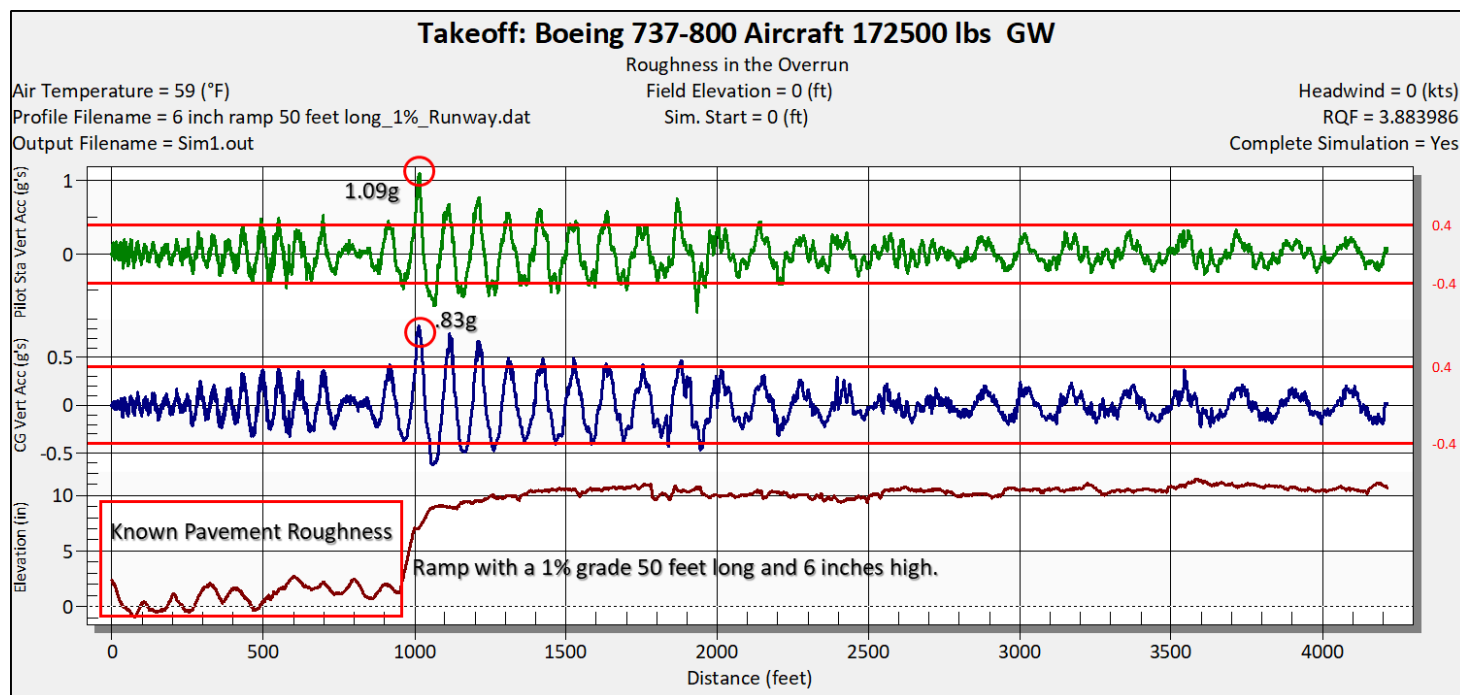


# 737-800 Takeoff on Runway with Known Roughness with NO RAMPS



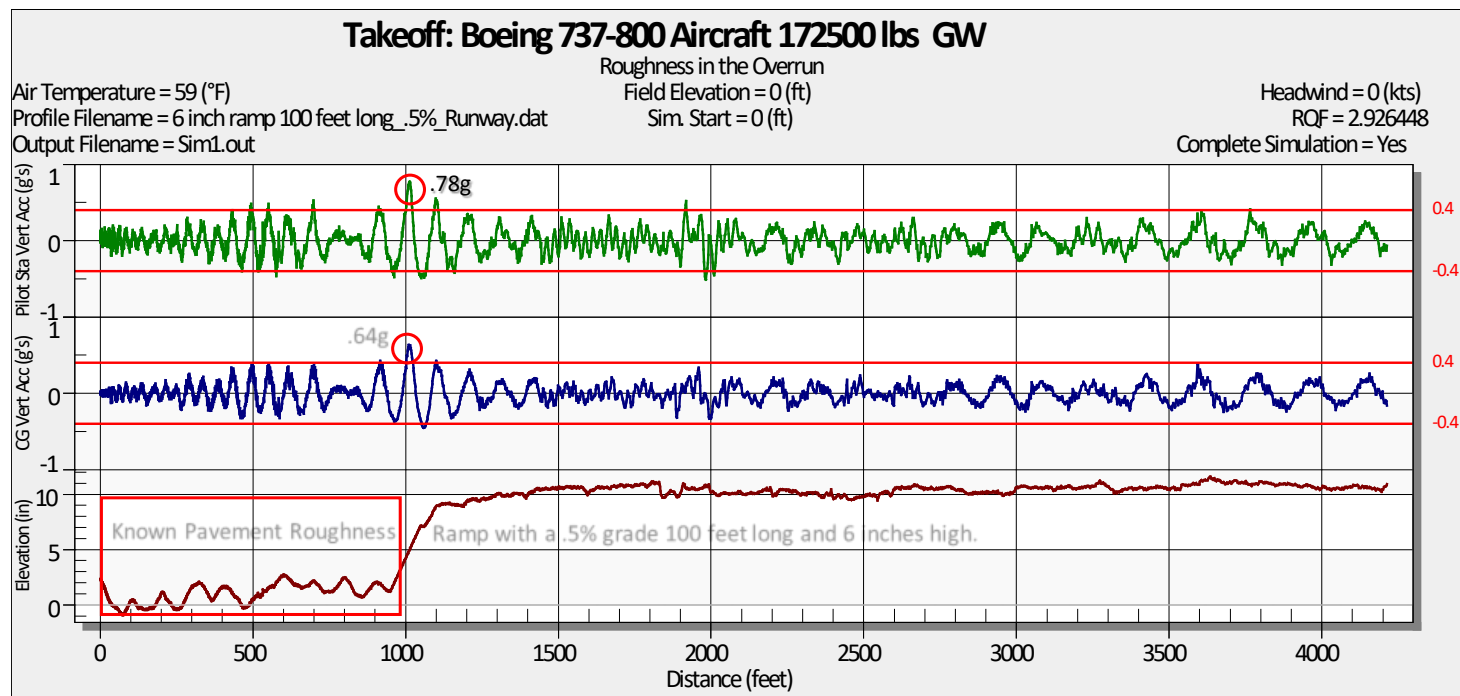
Level 1 Responses are Predicted

# Ramp 1, 50-Foot Long 1% Grade Inserted in Known Roughness



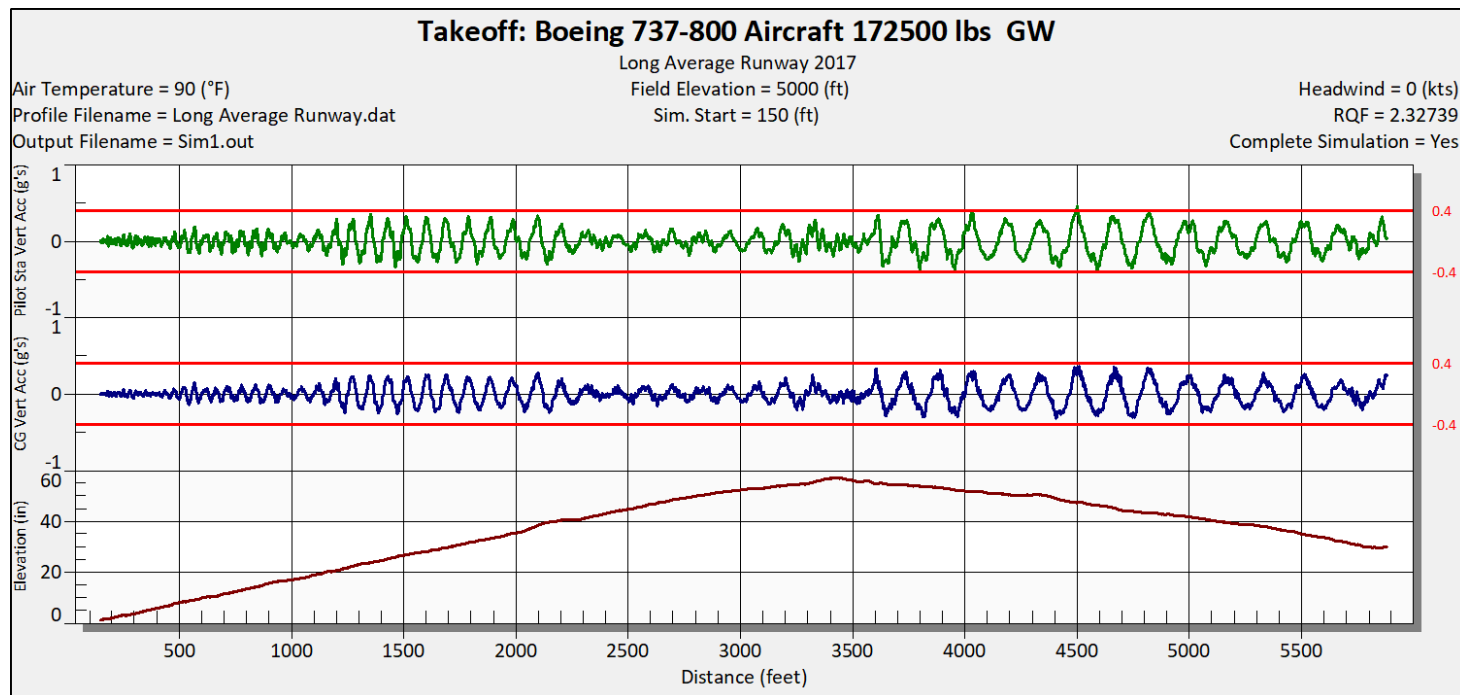
Level 3 Responses are Predicted

# Ramp 2, 100-Foot Long .5% Grade Inserted in Known Roughness



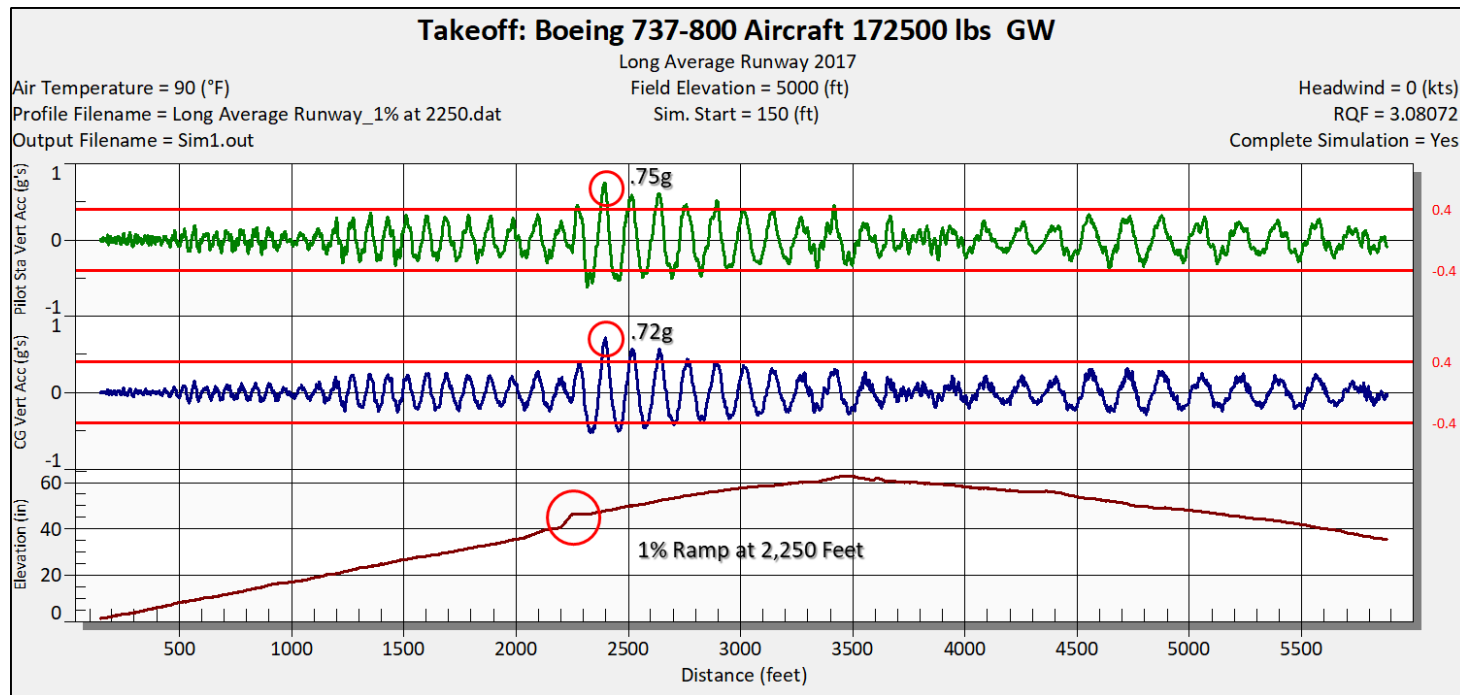
Level 2 Responses are Predicted

# Long Runway of Average Ride Quality



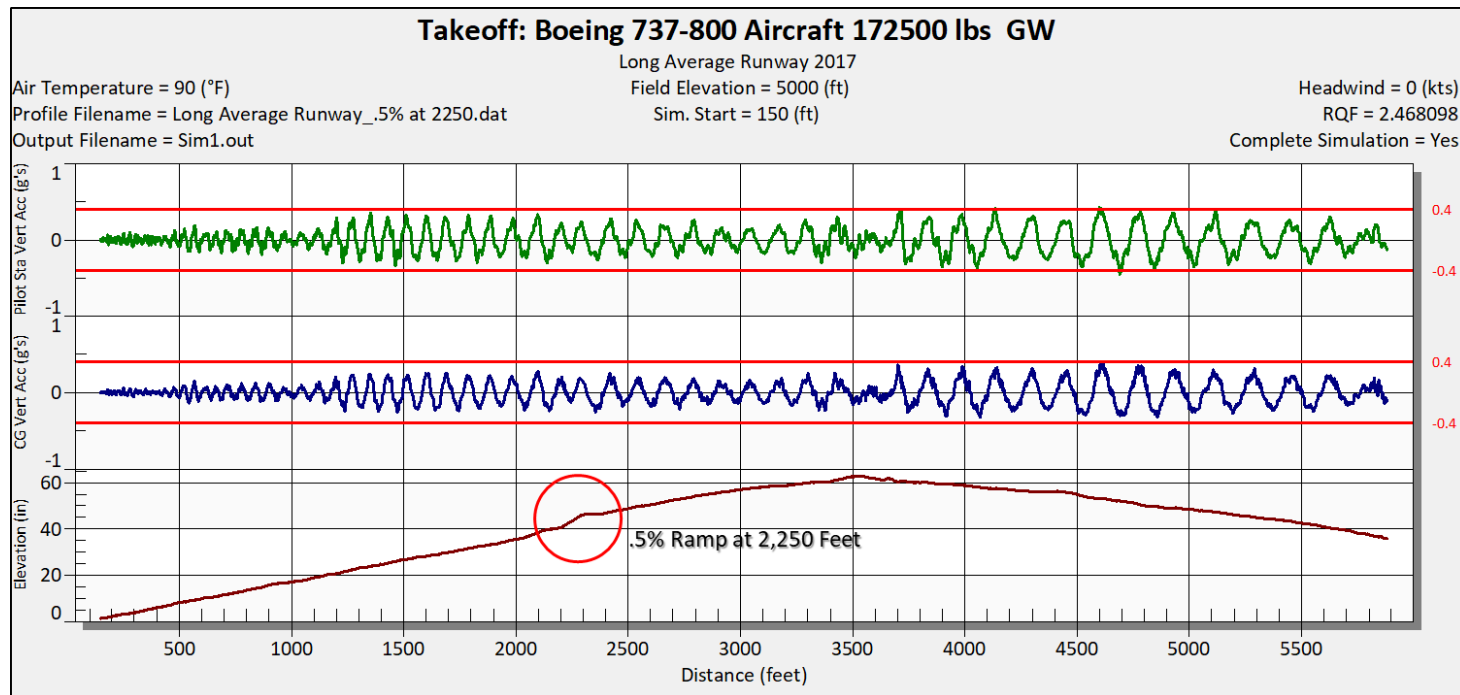
Acceptable Responses at the PSA and CGA are Predicted

# Long Runway of Average Ride Quality 1% 50-Foot Ramp at 2,250 Feet



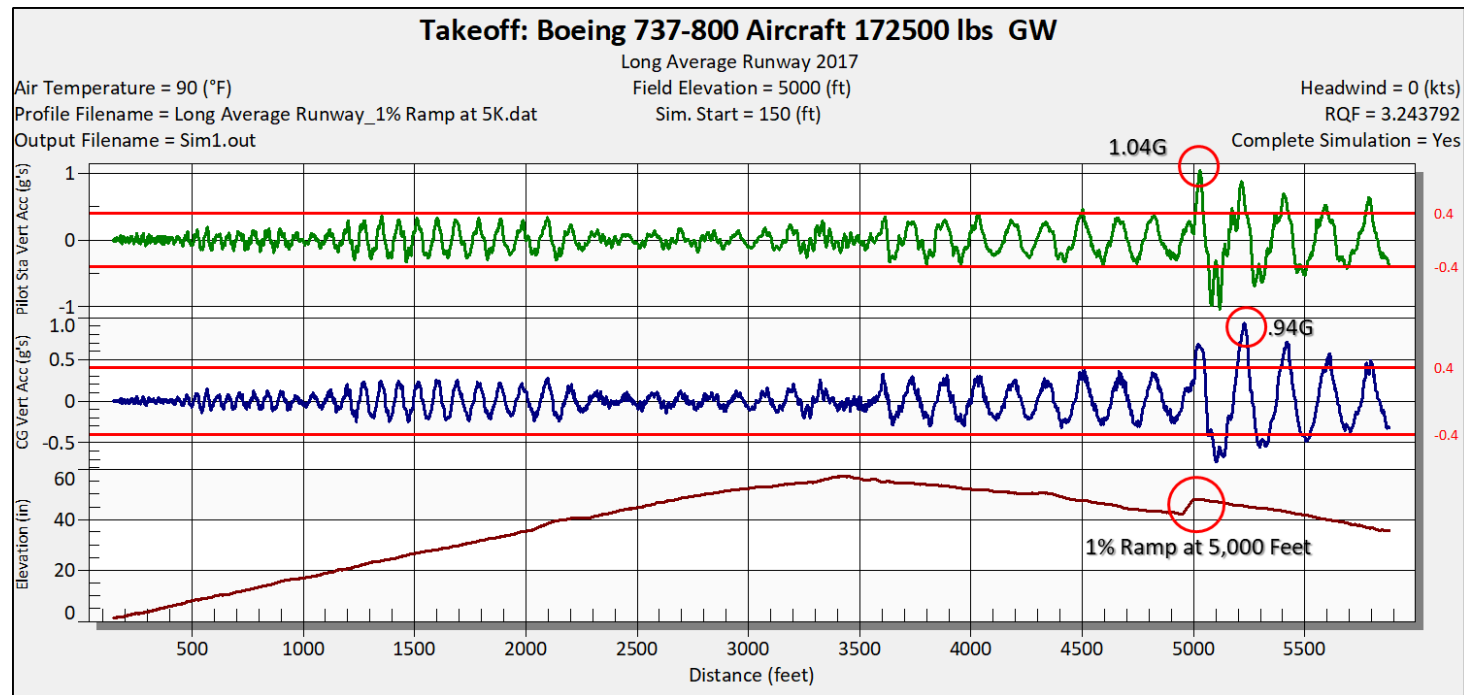
Level 2 Responses are Predicted

# Long Runway of Average Ride Quality .5% 100-Foot Ramp at 2,250 Feet



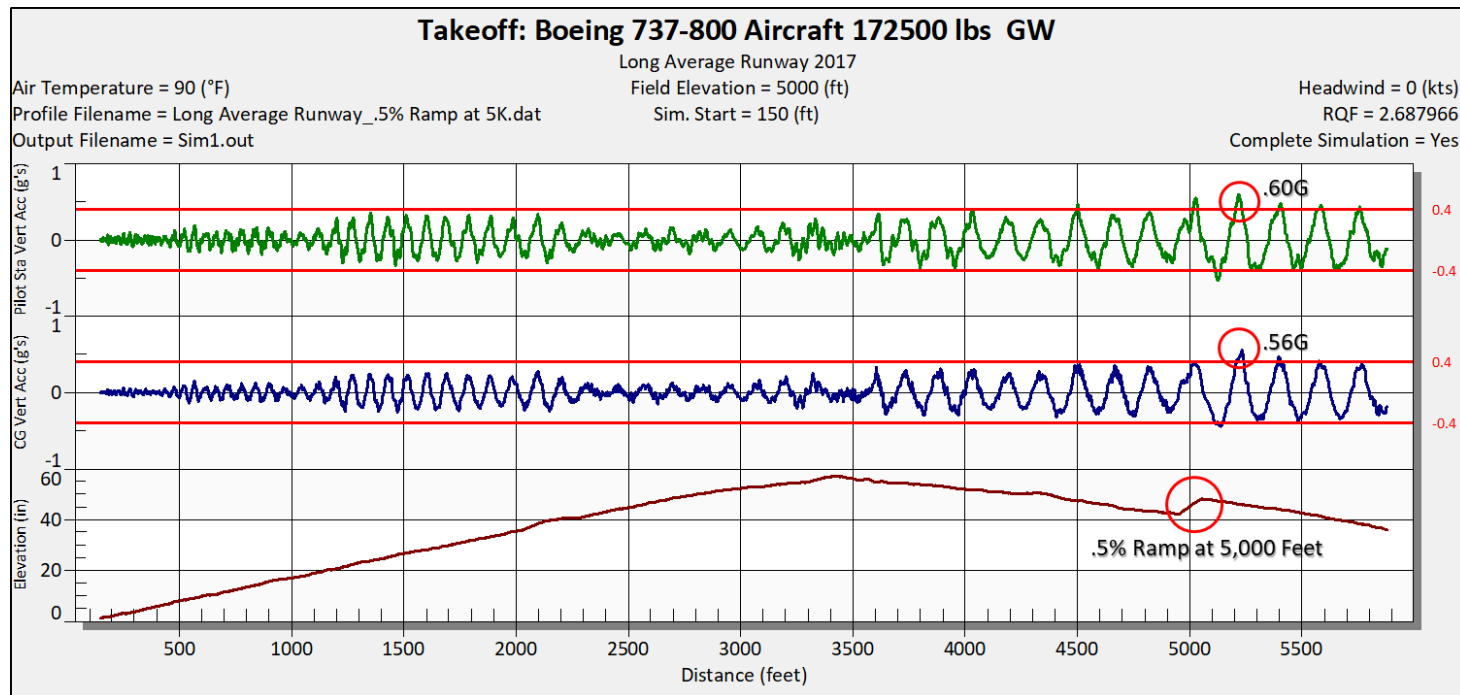
Acceptable Responses at the PSA and CGA are Predicted

# Long Runway of Average Ride Quality 1% 50-Foot Ramp at 5,000 Feet



Level 3 Responses are Predicted

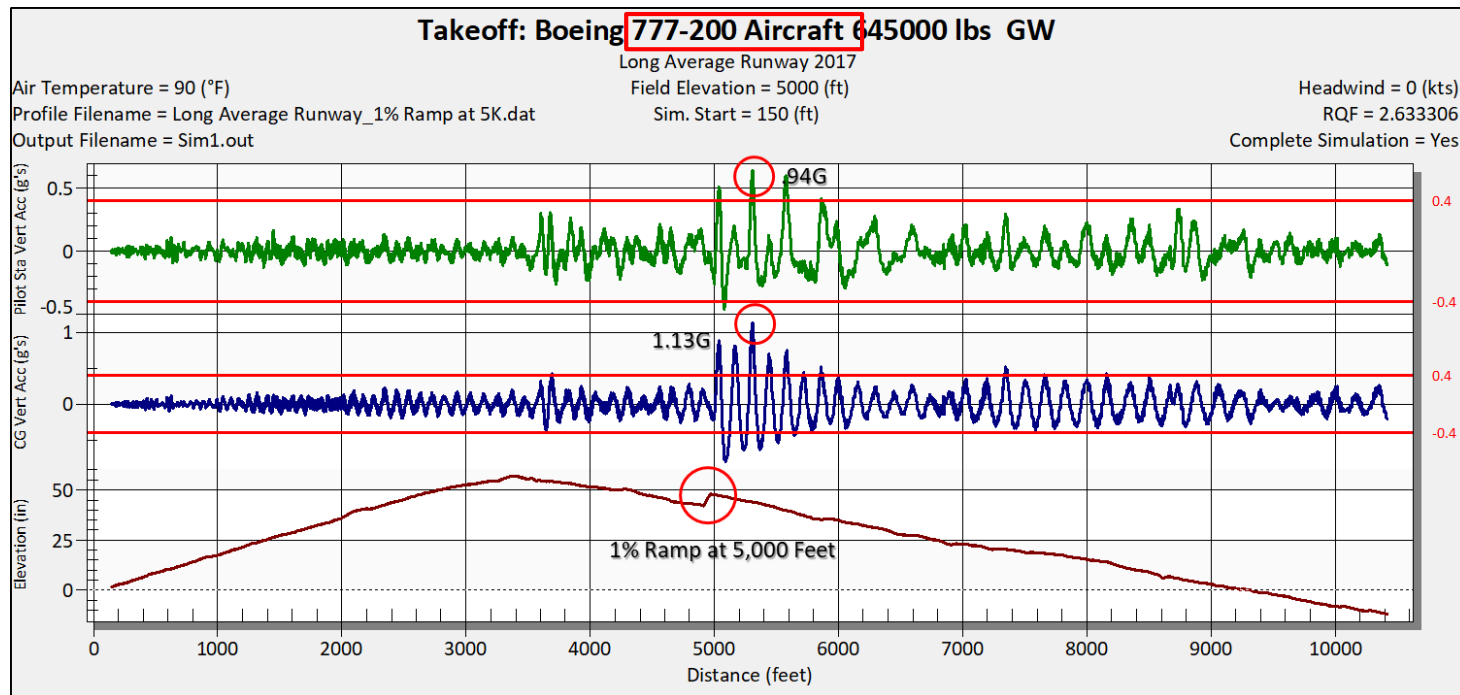
# Long Runway of Average Ride Quality .5% 100-Foot Ramp at 5,000 Feet



Level 2 Responses are Predicted

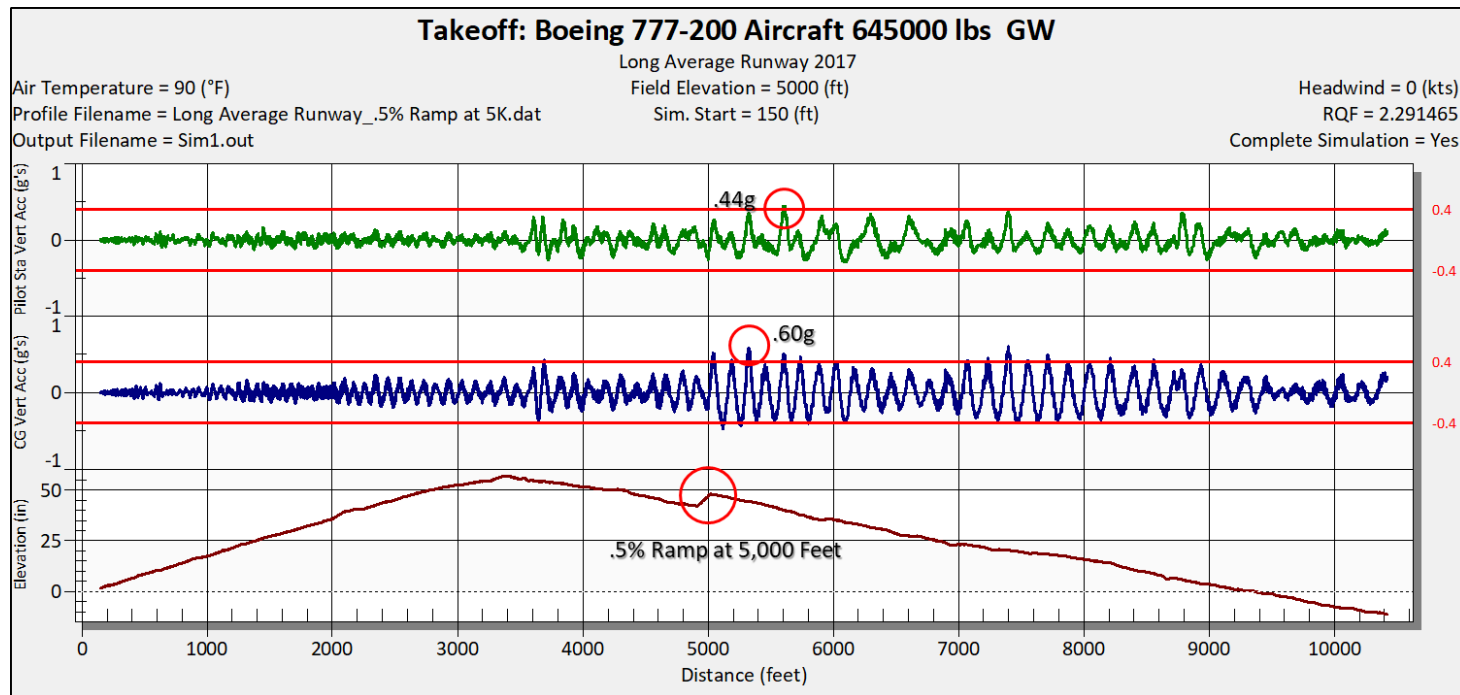


# Long Runway of Average Ride Quality 1% 50-Foot Ramp at 5,000 Feet



Level 3 Responses are Predicted

# Long Runway of Average Ride Quality .5% 100-Foot Ramp at 5,000 Feet



Level 2 Responses are Predicted

# Temporary Ramps and Aircraft Response

- The Rapid-Set PCC Overlay Could Require a Constant Thickness of Six Inches.
  - Questions Arose about the Affect of a Ramp of Six Inches on Aircraft Response
    - What is the Effect of a Short, Steep Ramp Vs. Longer, Shallower Ramp?
    - **Answer:** Longer and Shallower Ramps Produce Temporarily Acceptable Aircraft Response in Most Cases

# Temporary Ramps and Aircraft Response

- The Rapid-Set PCC Overlay Could Require a Constant Thickness of Six Inches.
  - Questions Arose about the Affect of a Ramp of Six Inches on Aircraft Response
    - What are The Limits of Acceptable Aircraft Response?
    - **Answer:** Boeing Identified Three Types of Roughness. Levels 1 and 2 are Acceptable for Temporary Use. Ramps that Produce Level 3 Roughness Should be Avoided.

# Temporary Ramps and Aircraft Response

- The Rapid-Set PCC Overlay Could Require a Constant Thickness of Six Inches.
  - Questions Arose about the Affect of a Ramp of Six Inches on Aircraft Response
    - What Affect Will the Level of Roughness of the Surrounding Pavement Have on Aircraft Response to the Temporary Ramp?
    - **Answer:** The Roughness of the Surrounding Pavement Plays a Large Role in Aircraft's Response to the Temporary Ramp.

# What Does this Tell Us?

- “Know Before You Go”
  - Evaluate the Runway’s Ride Quality During the Project’s Planning Stage
  - Could Become Valuable Insurance Policy



# Step One – Measure the Runway's Profile

- Variety of Devices to Measure the Runway's Profile
  - Important to Measure Long Wavelengths – 300 feet
  - Good Idea to Measure Multiple Lines of Survey in the Runway's Keel Section
  - Lines of Survey Should be Repeatable with One Another



External Reference



Inclinometer



Inertial Profiler

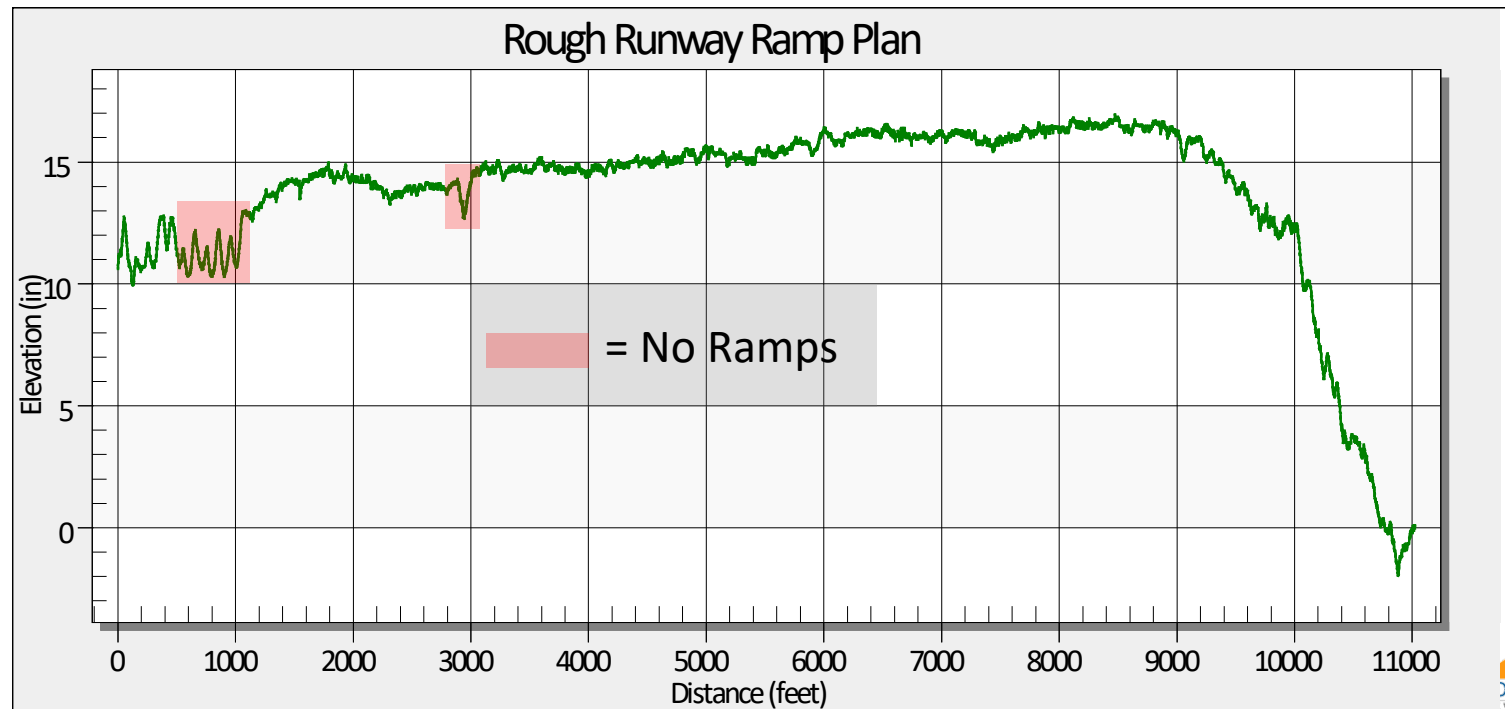
# Step Two – Evaluate the Profile Data

- Aircraft Simulation
  - Multiple Aircraft Types
  - Conduct Multiple Operation Types (Takeoff and Landing)
- FAA AC 150/5380-9
  - Will Categorize Event As Acceptable, Excessive or Unacceptable
  - Caution: Indexes Can Mischaracterize Roughness Events
    - Is Not Speed or Aircraft Specific



# Create Plan

- Create a Paving Plan that can Avoid a Ramp in Areas of Roughness



# Other Recommendations

- Most Simulations Indicate that the .5% 100 Feet Long Produces Temporarily Acceptable Aircraft Responses
- A Down Ramp is Better than an Up Ramp
  - The Aircraft Typically Produces Less Response Encountering A Down Ramp
  - Place Down Ramps in the Primary Direction of the Traffic Flow

# The End



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