Runway Grooving and Surface Friction

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ALACPA X
Mexico City
September 30 to October 4, 2013

Problem: The Water Covered Runway

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Problem: The Water Covered Runway

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Runway Grooving

- Misconceptions Have Developed Relative to Its Purpose During Its More Than 40 Years of Application.

Runway Grooving

- Prudent to Stress Reasons for Which It Is Not Used

Runway Grooving

- <u>Not</u> <u>Used</u> to Provide <u>Drainage</u> of Water from the Pavement Surface

Drainage

- Provided by the Transverse Slope of the Pavement Surface
- Grooves Are Cut in the Runway Surface Transversely to the Pavement Centerline and Make a Secondary Contribution to Drainage.
- Grooves Do Reduce the Level of Standing Water as the Pavement Floods or Drains.

Runway Grooving

- Not Used to Provide an Increase in the Friction Capability of the Pavement Surface

Friction

- Friction Capability of the Pavement Surface Provided by the Quality of the Microtexture - Macrotexture Combination

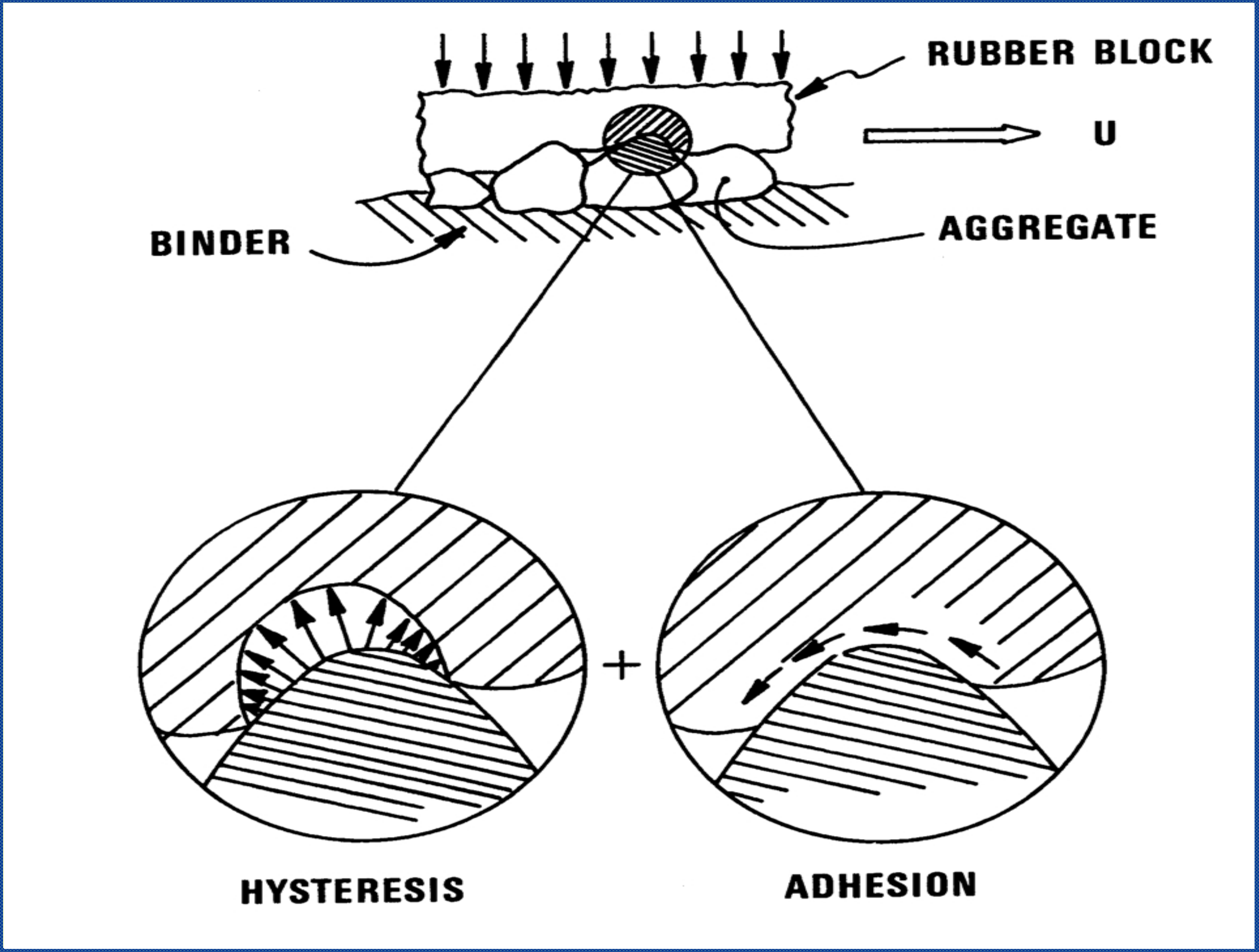
Friction Provides the Skid Resistance

Skid Resistance by Other Names

- Friction
- Friction Coefficient
- Braking Coefficient

Mechanism of Friction

Courtesy of Dr. Satish K. Agrawal of the FAA Technical Center



Runway Grooving

- Provides Forced Water Escape from the Pavement Surface under Aircraft Tires Traveling at High Speed

Runway Grooving

- Does Not Eliminate Hydroplaning
- <u>Reduces</u> <u>Hydroplaning</u> to a Manageable Level
- A <u>Higher</u> <u>Degree</u> of <u>Contact</u> is Maintained Between <u>Aircraft</u> <u>Tires</u> and the <u>Pavement</u> <u>Surface</u> under the Condition of Standing Water.

Runway Grooving

- Enables Pavement Surface Microtexture - Macrotexture Combination to Provide Sufficient Braking and Directional Control to Aircraft
- Effectiveness Increases from Slight to Significant as Speed of Aircraft or Water Depth on Pavement is Reduced

Runway Grooving

Runway Grooving

- Reduces Dynamic Hydroplaning (Standing Water)
- Reduces Viscous Hydroplaning (Wet Pavement with Little to No Standing Water)

Functions of Runway Surface Characteristics in the Presence of Water

- Transverse Slope Provides Drainage.
- Texture of Pavement Provides Friction.
- Grooving Enables Aircraft Tires to Contact the Pavement.

Runway Grooving

- In the Presence of Water, Totally Worn Aircraft Tires Experience Better Braking on a Grooved Pavement than Newly Treaded Tires on a Nongrooved Pavement.

Porous Friction Course Substitutes for Runway Grooving

- Provides Drainage of Water from the Pavement Surface (Primary)
- Provides Forced Water Escape from the Pavement Surface under Aircraft Tires Traveling at High Speed Similar to Grooving (Secondary)
- Application Limited Relative to Density of Aircraft Operations

Not Substitutes for Runway Grooving

- Tire Tread (Demonstrated in Full Scale Tests)

- Coarse Pavement Surface Macrotexture (Demonstrated to a Limited Degree in Full Scale Tests)

Grooving vs. Macrotexture

- Grooving Lies Below the Pavement Surface. Flexibility of Tire Cannot Seal the Path of Water Escape.

- Macrotexture Is the Pavement Surface. Flexibility of Tire Can Seal the Path of Water Escape.

Grooving vs. Macrotexture

- Macrotexture Is a Component of the Pavement Surface Friction.

- Inferences Drawn from Limited Available Data Indicate that the Effectiveness of Macrotexture in Providing Rapid Water Evacuation from Beneath Aircraft Tires Is Questionable.

Grooving vs. Macrotexture

- Term "Surface Cavity" is Introduced in Order to Make the Comparison.
- Surface Cavity is Produced by Grooving or Macrotexture.
- Inferences Drawn from Limited Available Data Indicate that, for Comparable Surface Cavity, Grooving Is More Effective than Macrotexture in Reducing Hydroplaning.

Grooving vs. Macrotexture

FAA Full Scale Test Program Braking/Hydroplaning

- 1975 to 1983
- 600 Full Scale Tests
- Dynamic Test Track
- Asphalt and Portland Cement Concrete
- Variety of Pavement Surface Treatments
- Wet to Flooded Conditions
- Speeds of 30 to 150 Knots

FAA Full Scale Test Program Braking/Hydroplaning

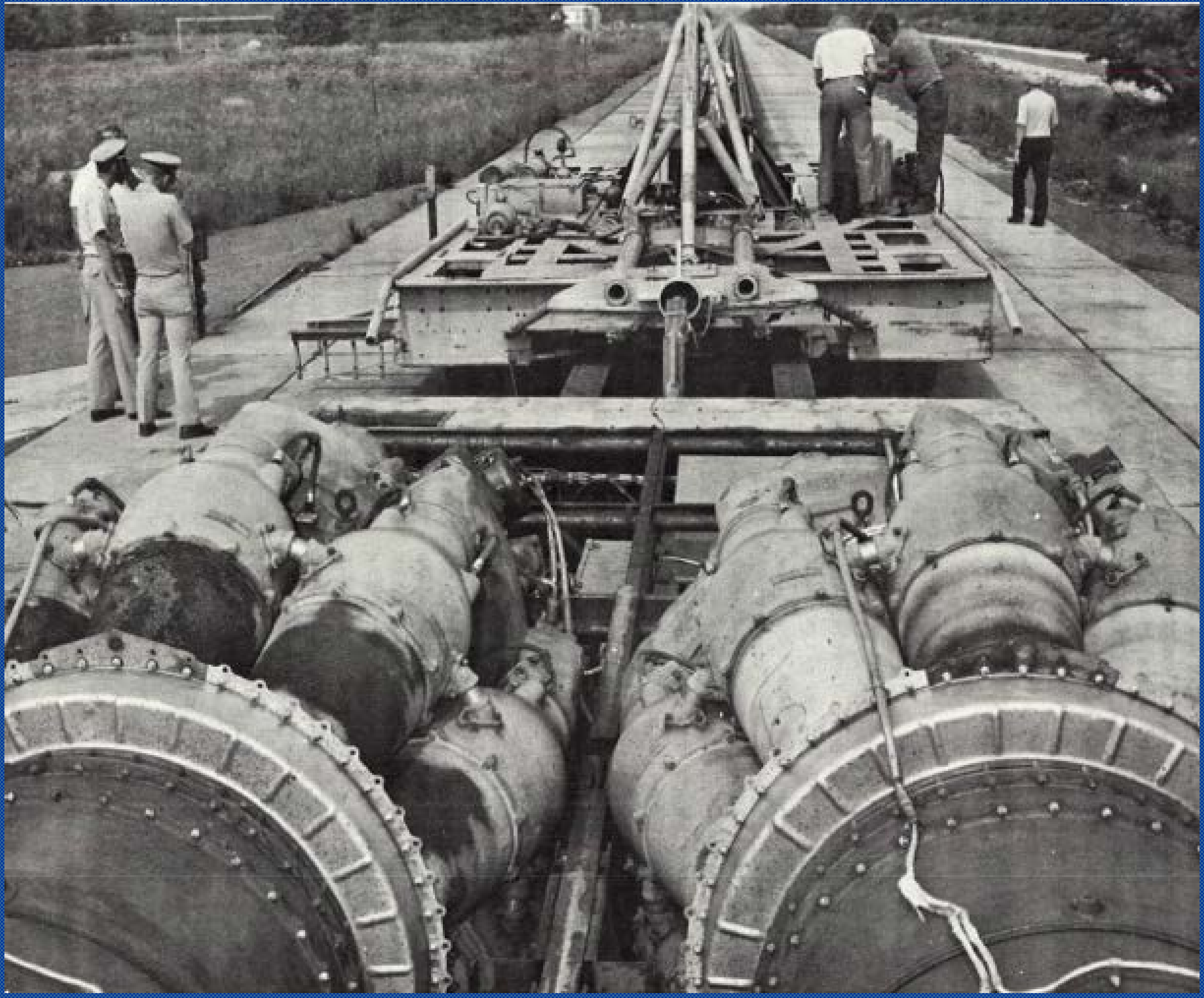
- Aircraft Tire, 49 by 17, 26 ply, type VII (Boeing 727 and 747)
- Tire Pressure, 140 psi
- Wheel Load, 35,000 lbs
- Maximum Braking Data Base
- Test Facility, NAEC (Navy), Lakehurst, New Jersey

FAA Full Scale Test Program Braking/Hydroplaning Water Depth Conditions on Pavement

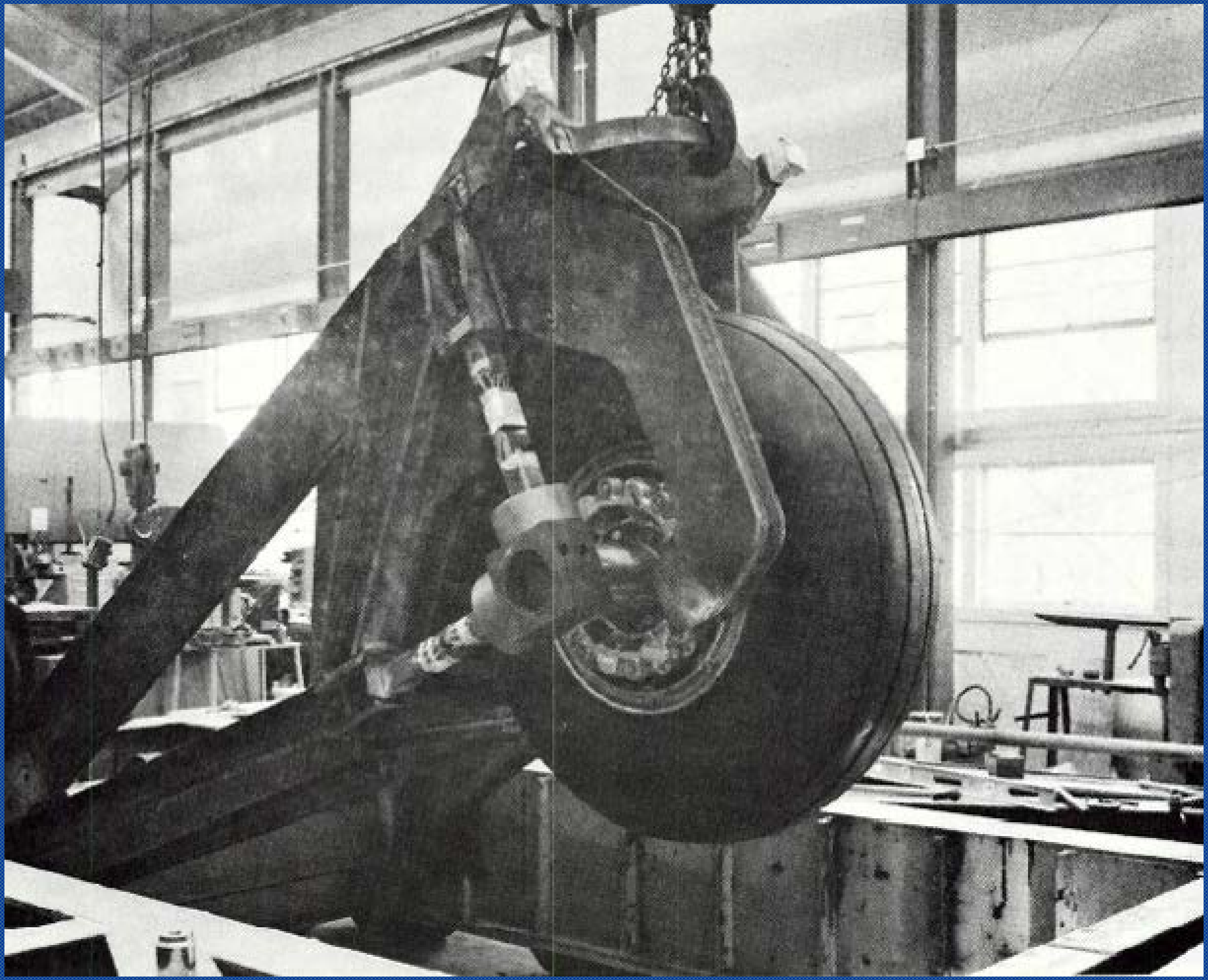
- Wet 0.00 in. Standing Water
- Puddled 0.10 in. Standing Water
  2.54 mm
- Flooded 0.25 in. Standing Water
  6.35 mm

Launch End of Test Track

Launch End of Test Track

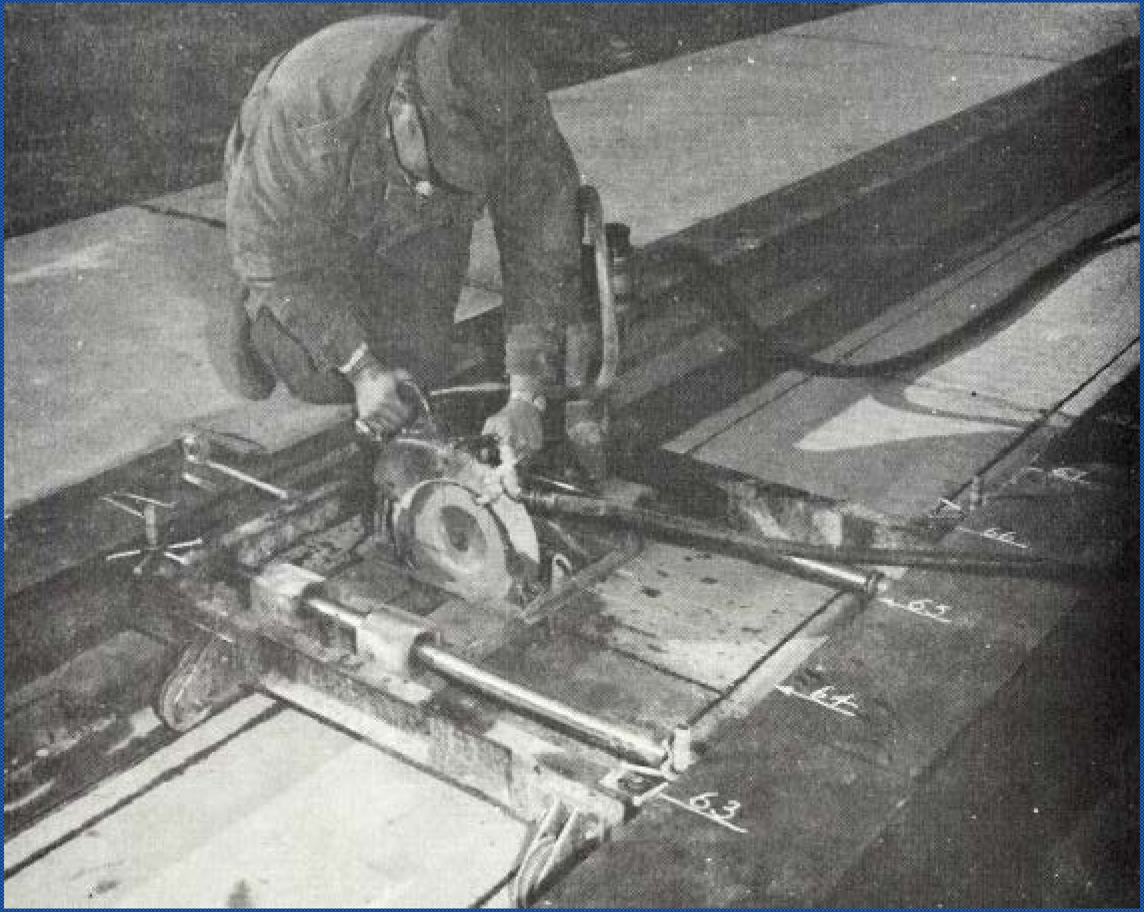


Dynamometer with Tire-Wheel Assembly



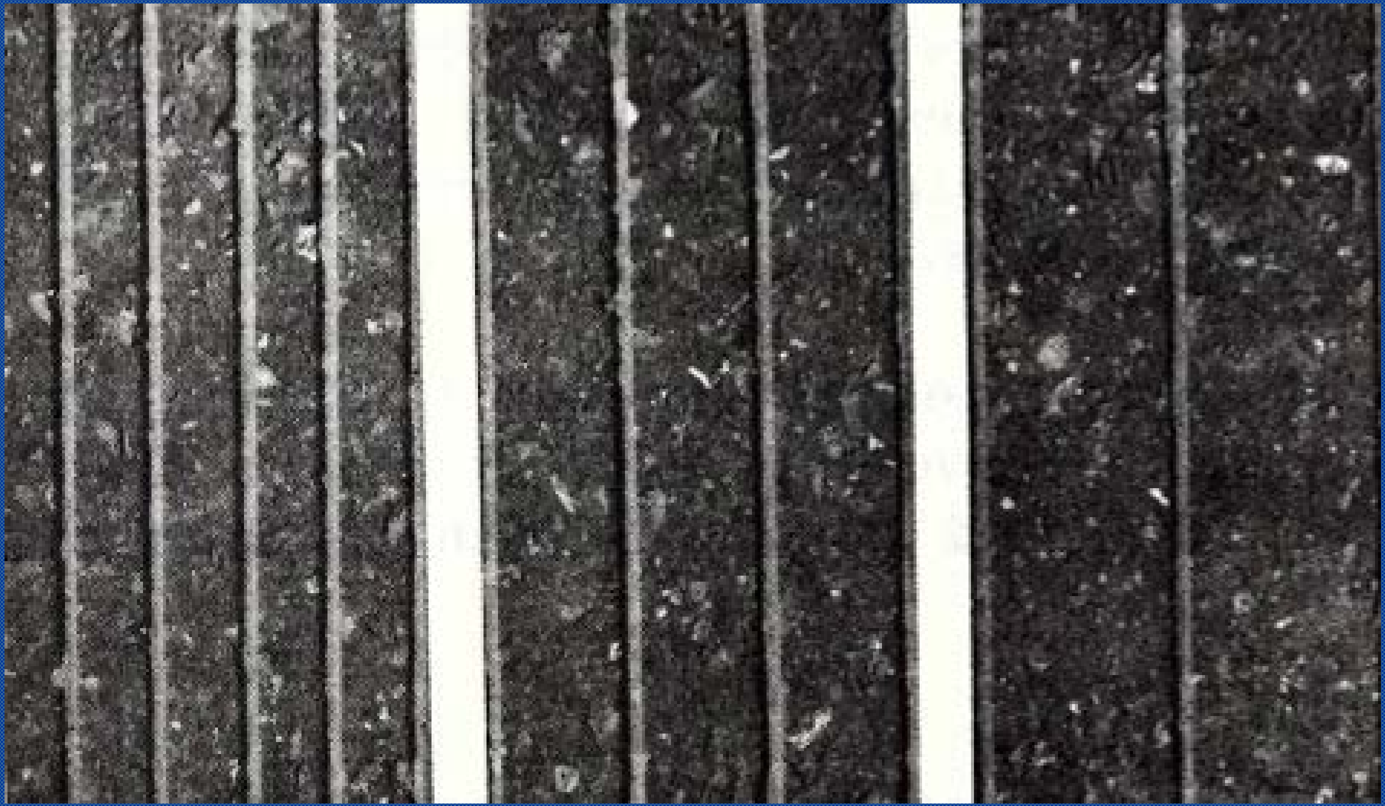
New and Worn Tire Tread

Saw Cutting Grooves in the Test Pavement

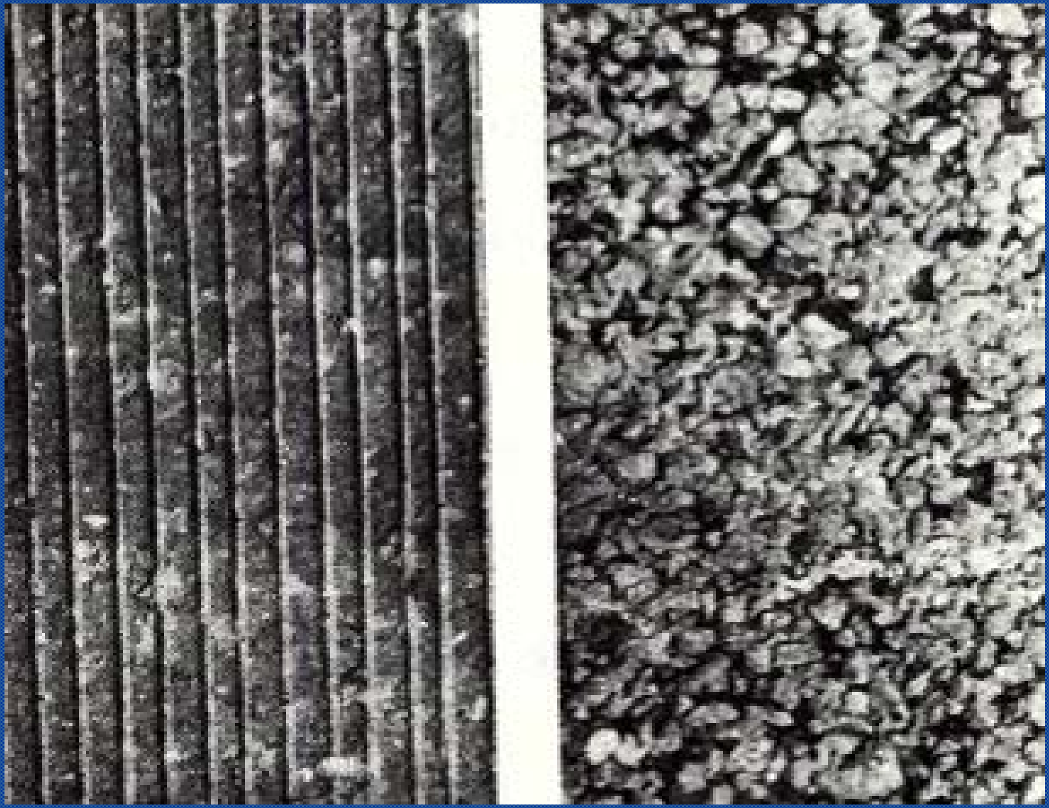


Test Pavement at the Recovery End of the Test Track

1/4 x 1/4 in. Grooves Spaced at 1 1/4 , 2, and 3 ins.



1/8 x 1/8 in. Grooves Spaced at 1/2 in. and Porous Friction Course

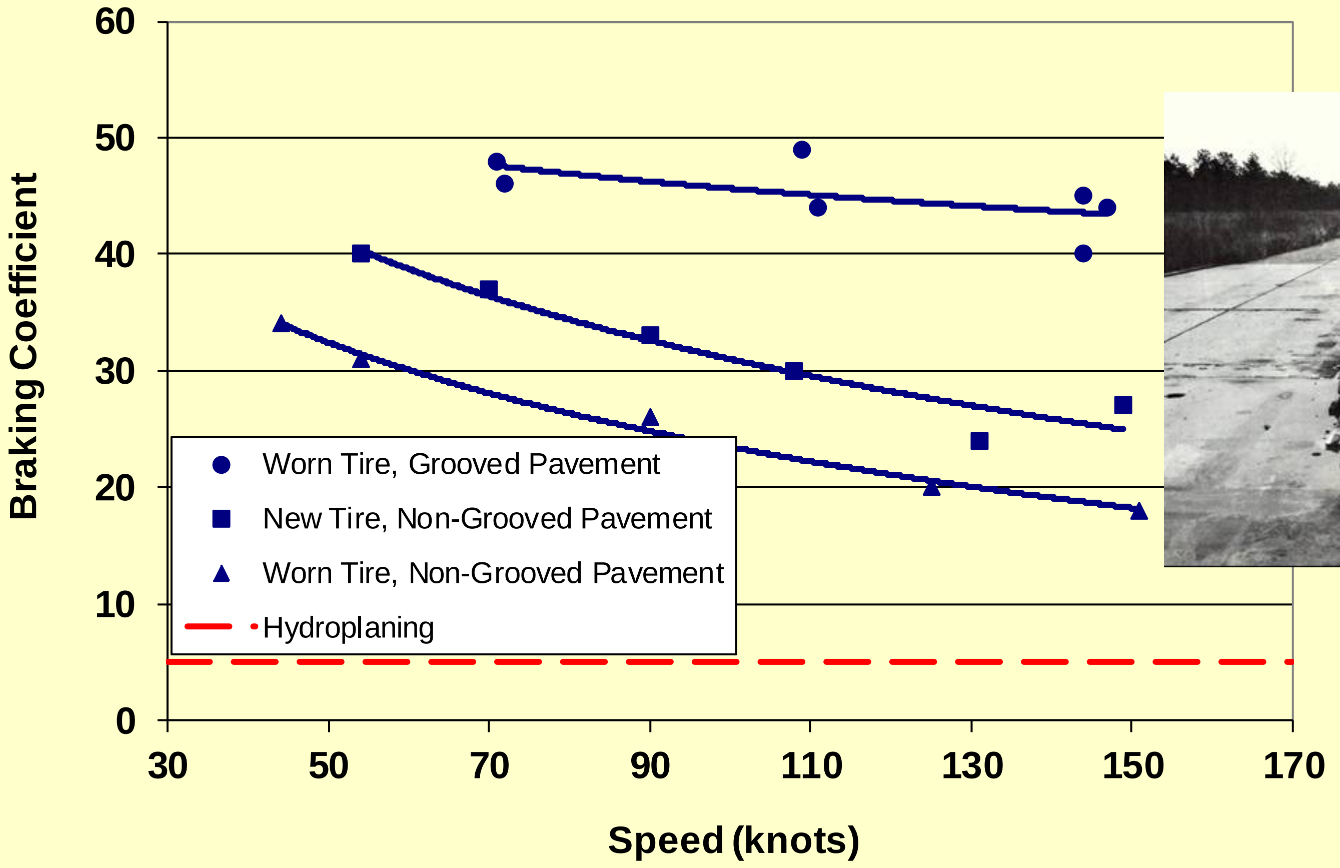


Experimental Percussive Grooves at 3 in. Spacing

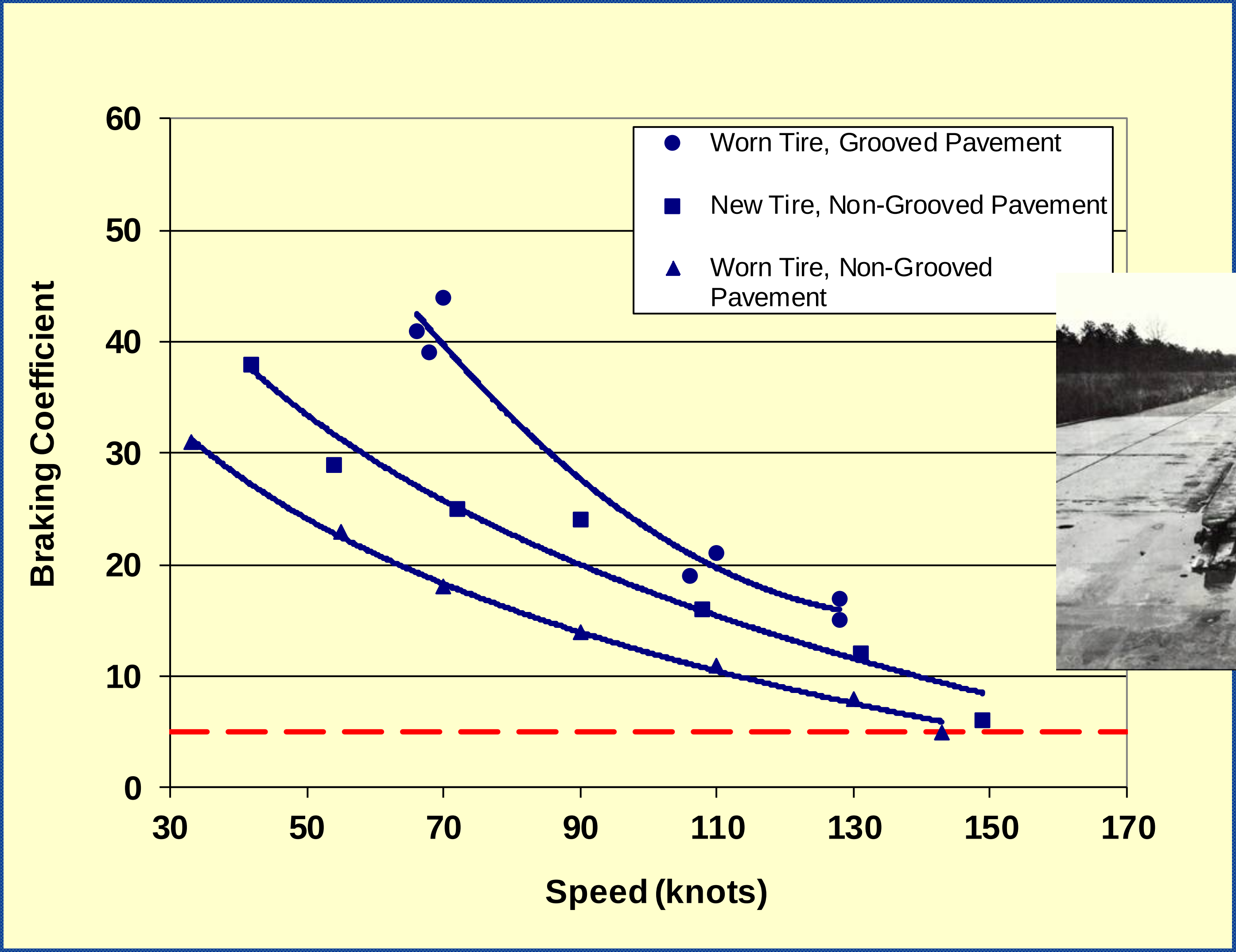
Grooved Pavement

- FAA Standard 1/4 x 1/4 Saw-Cut Grooves Spaced at 1½ inches
- Represented by Curve Fits between Data Points for 1¼ inch and 2 inch Spacing
- FAA Standard in Metric:
  6mm x 6 mm Grooves Spaced at 38 mm

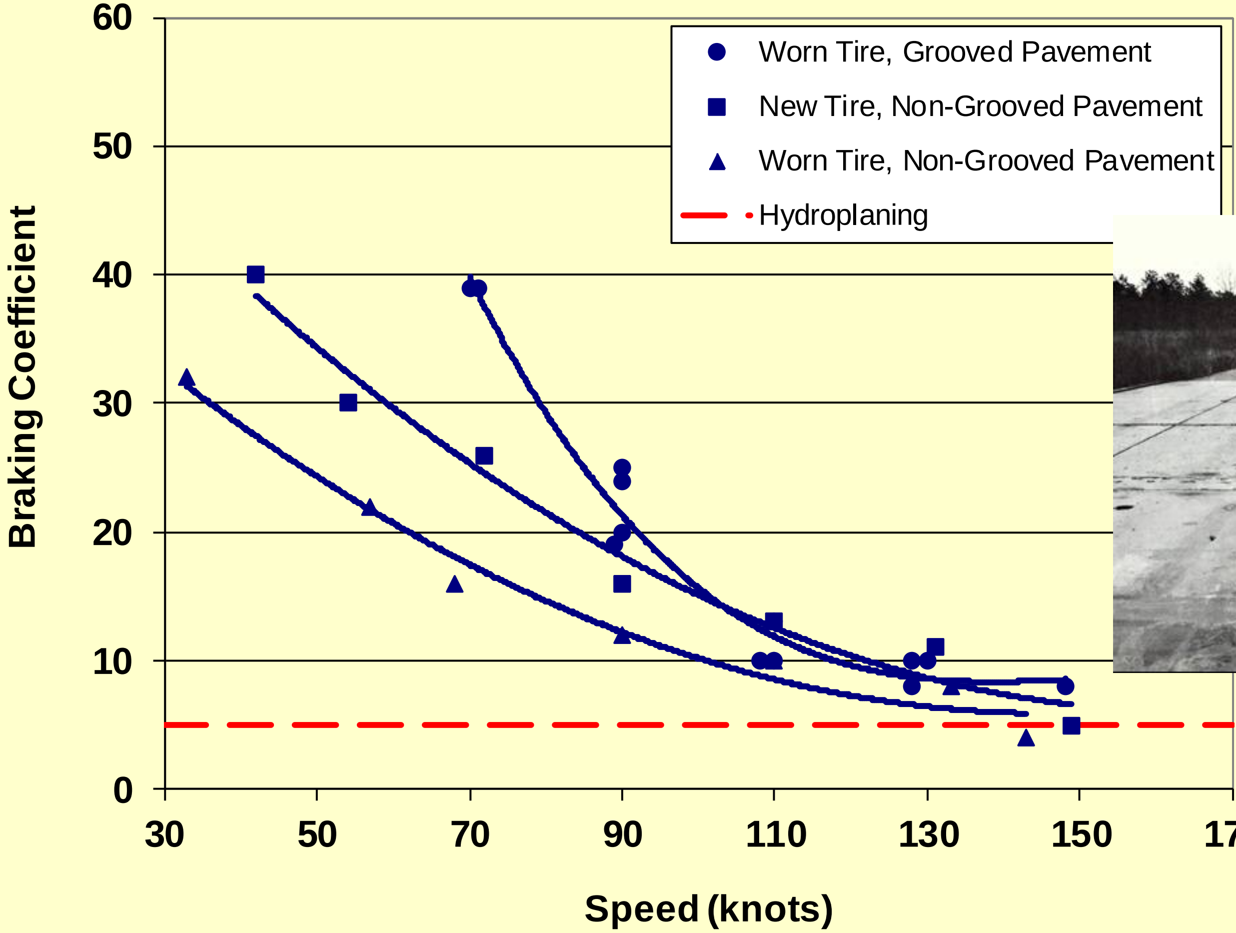
Braking on a Wet Asphalt Pavement



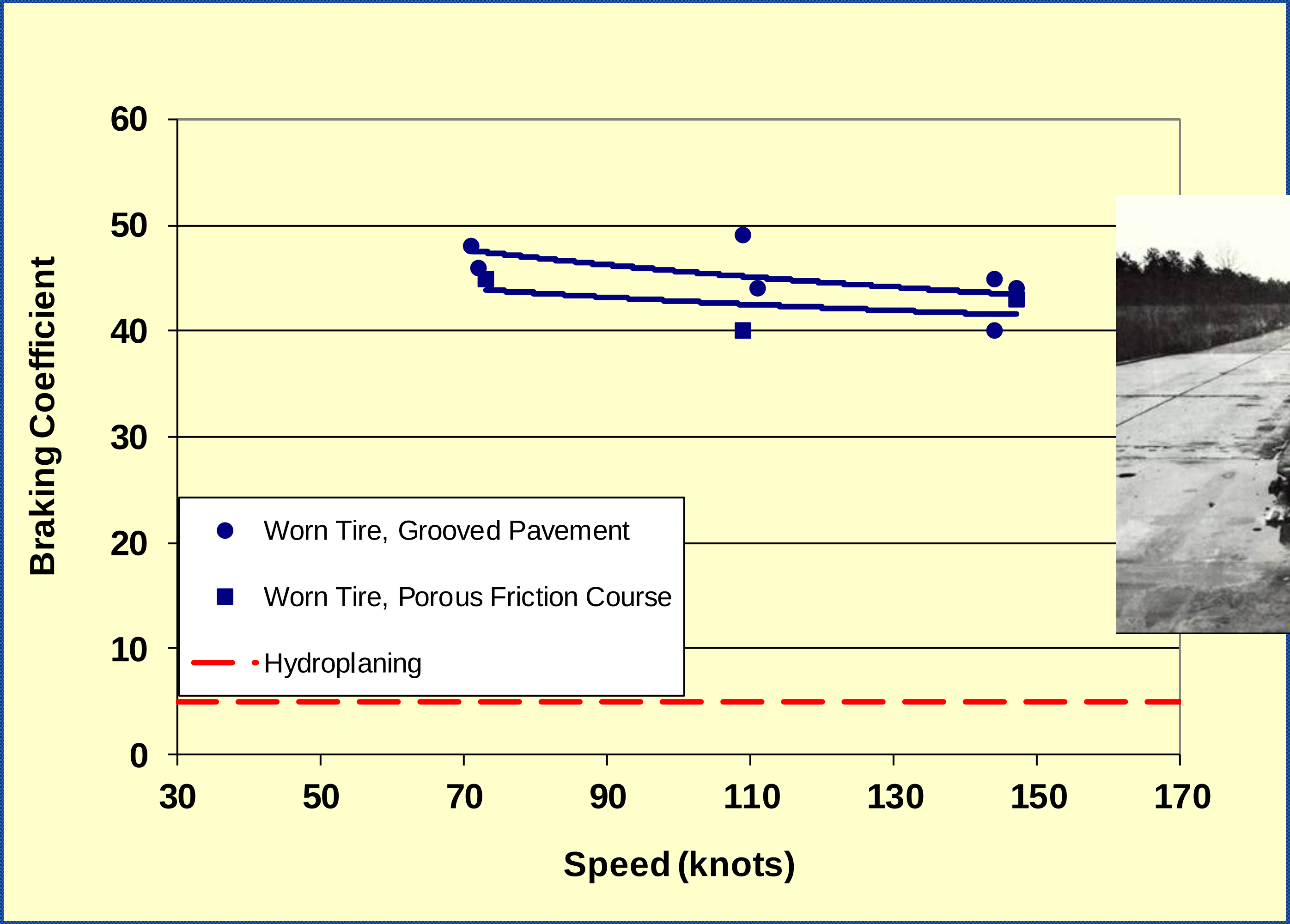
Braking on a Puddled Asphalt Pavement



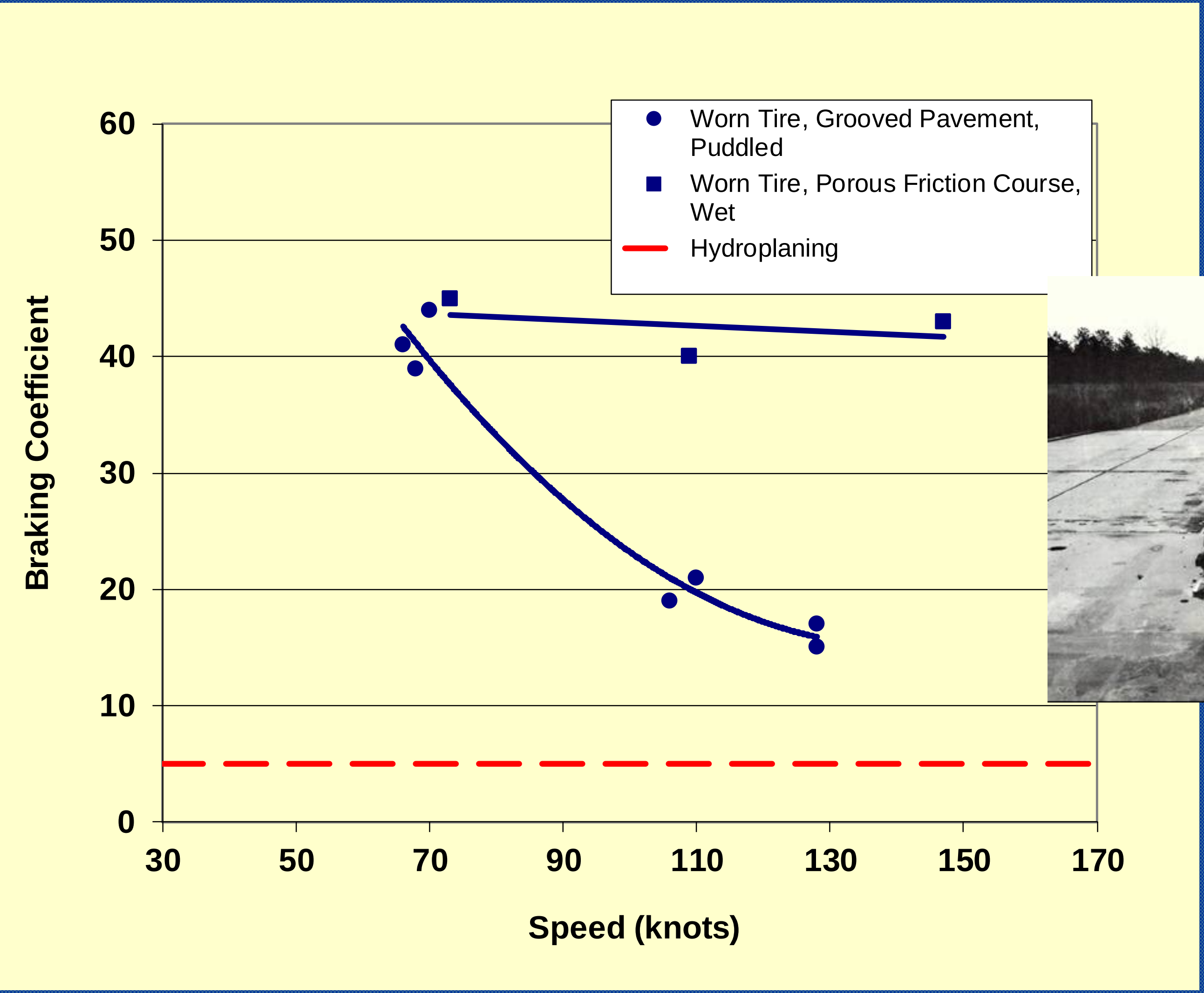
Braking on Flooded Asphalt Pavement



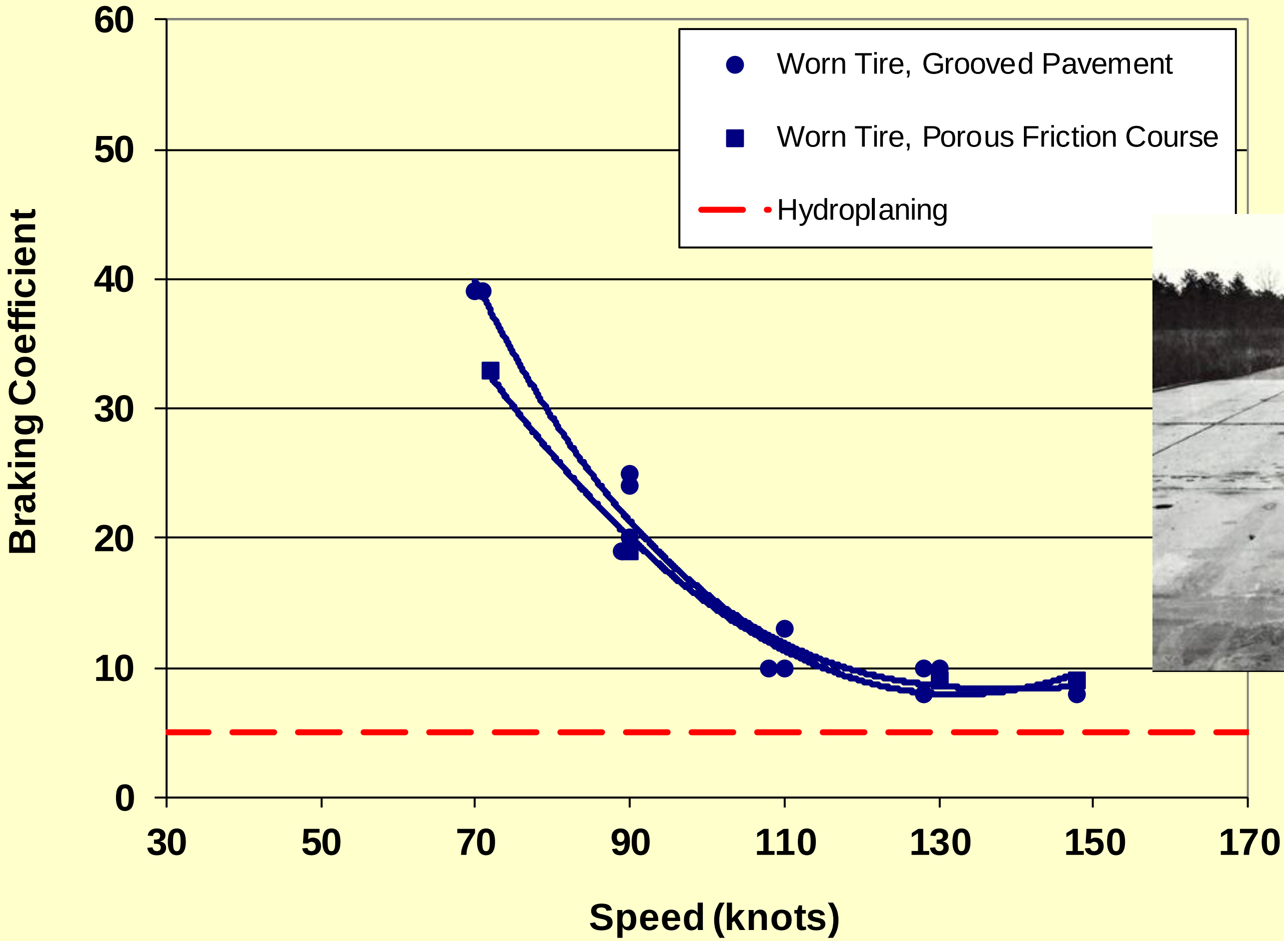
Braking on a Wet Asphalt Pavement



Braking on an Asphalt Pavement Under a Heavy Downpour



Braking on an Asphalt Pavement Under a Heavy Downpour (Flooded)



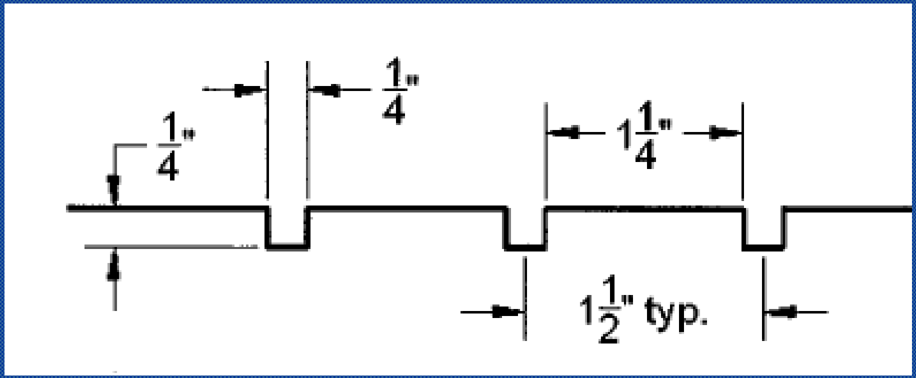
Essentials of an Aircraft Braking/Hydroplaning Test System

- Full Scale
- High Speed
- Standing Water
- Uniformity of Water Depths
- Close Control of Variables

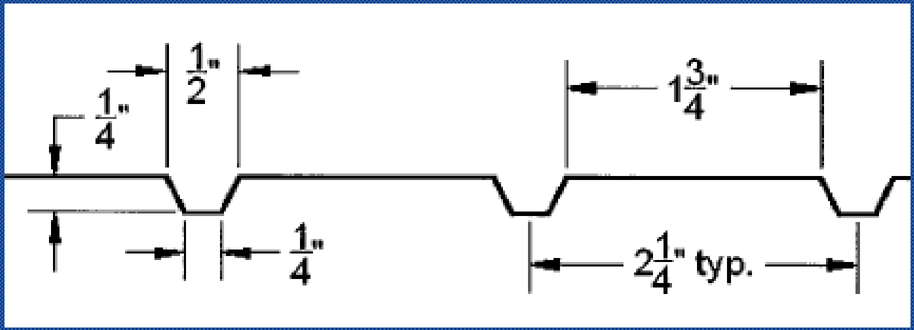
Aircraft Braking/Hydroplaning Test System Scenarios

- Full Scale Tire-Wheel Assembly on a Dynamic Test Track (Best Control of Variables)
- Aircraft on a Runway

FAA Standard and Proposed Saw-Cut Groove Patterns

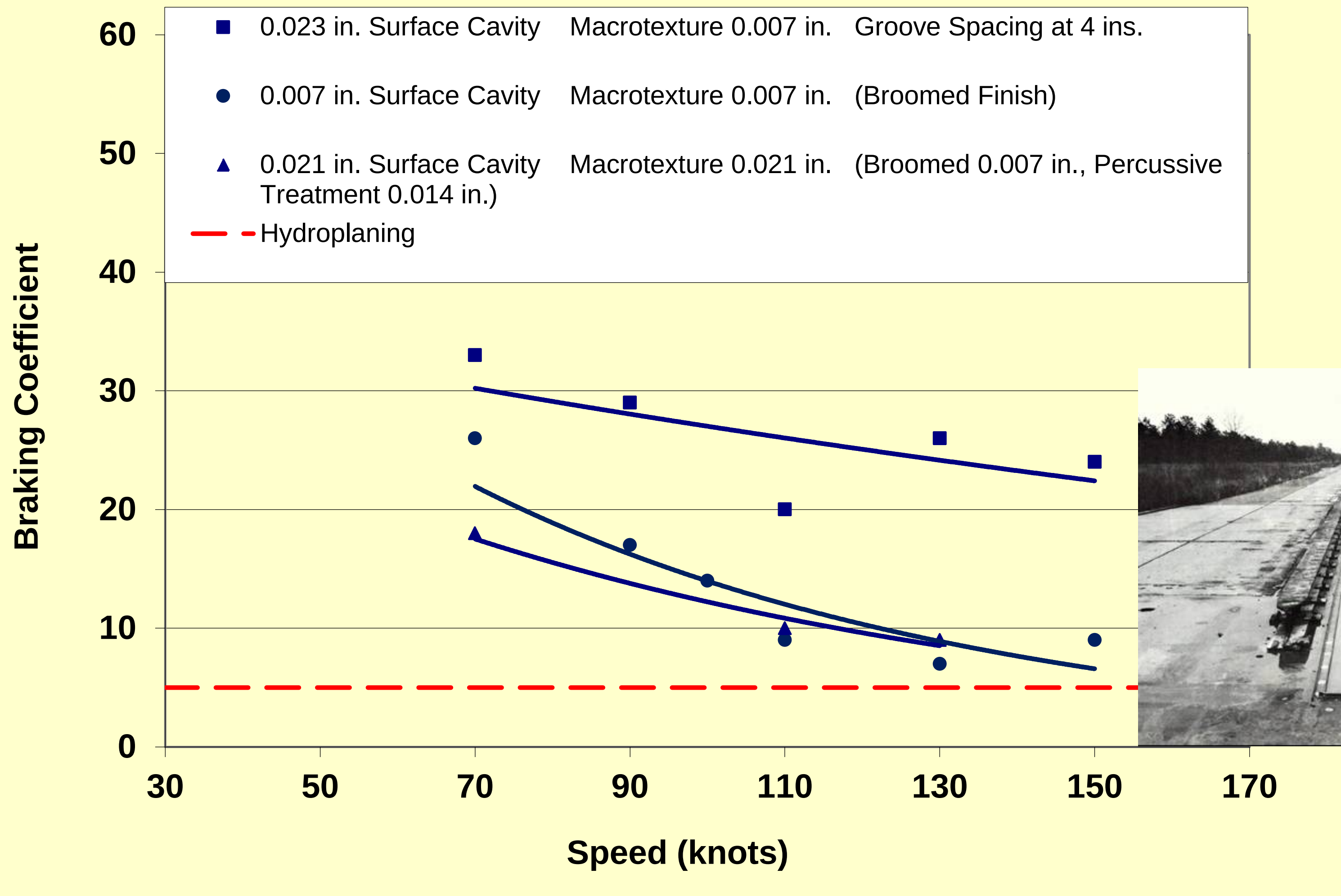


Standard

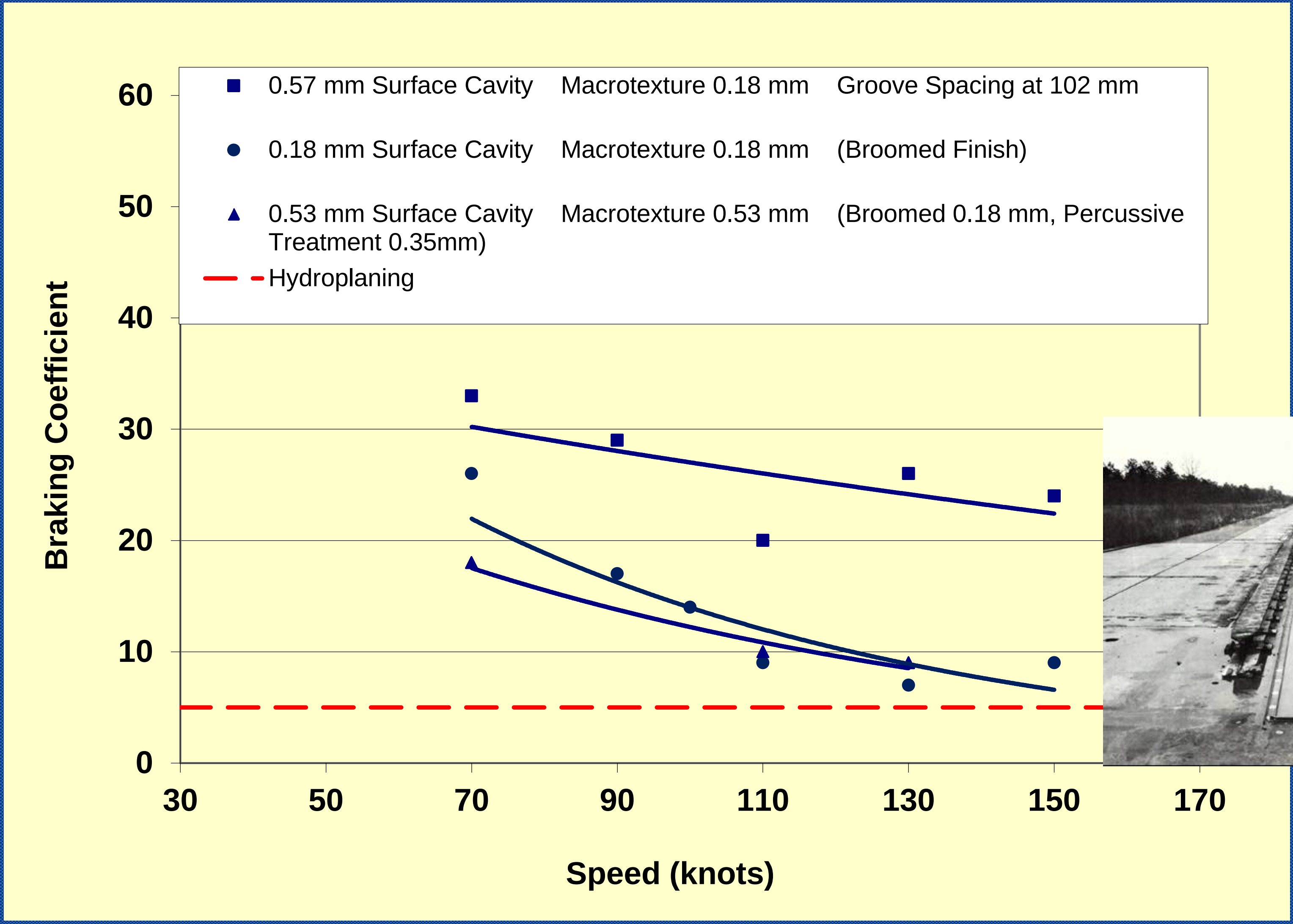


Proposed

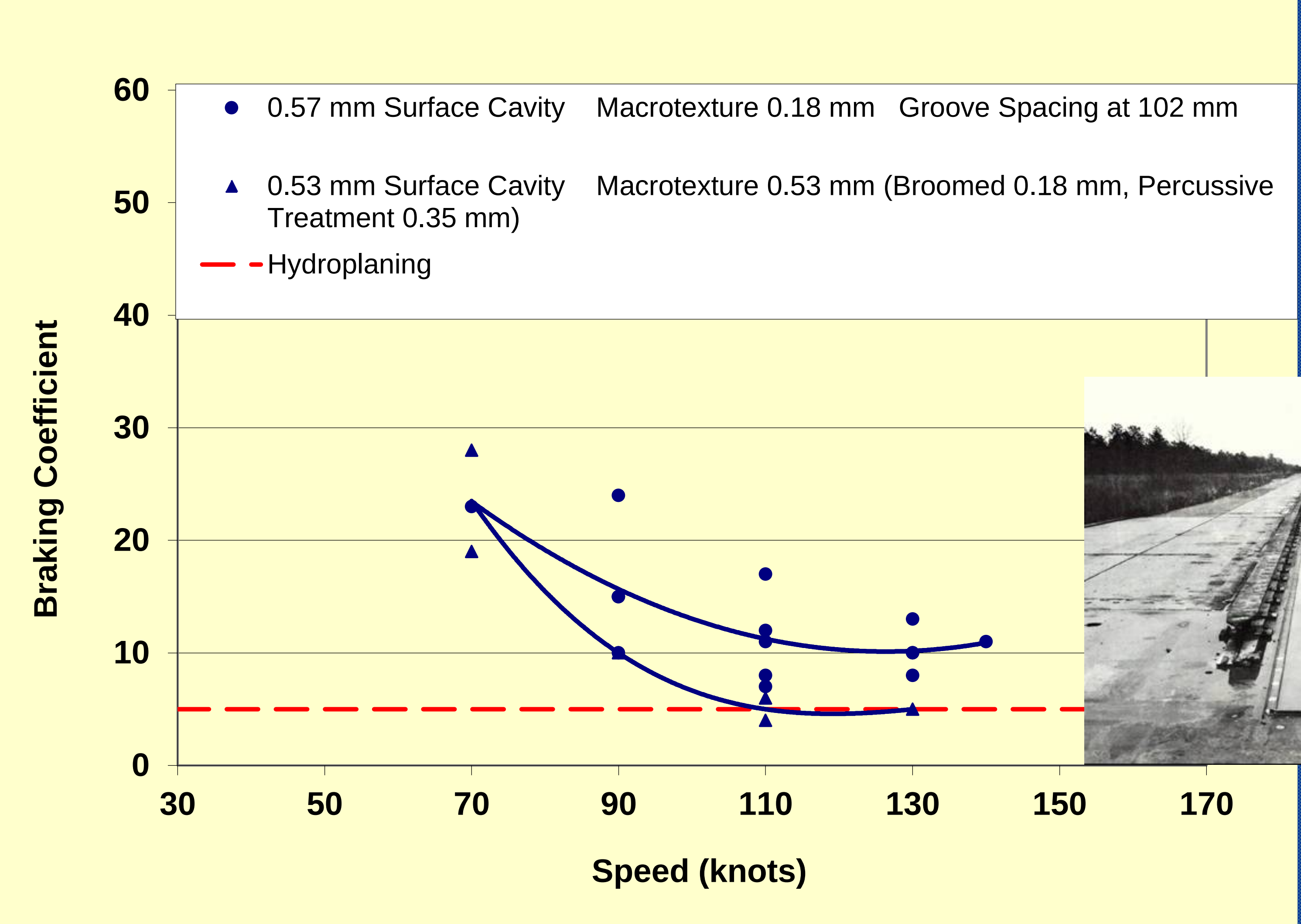
Grooving vs. Macrotexture Worn Tire on a Wet PCC Pavement



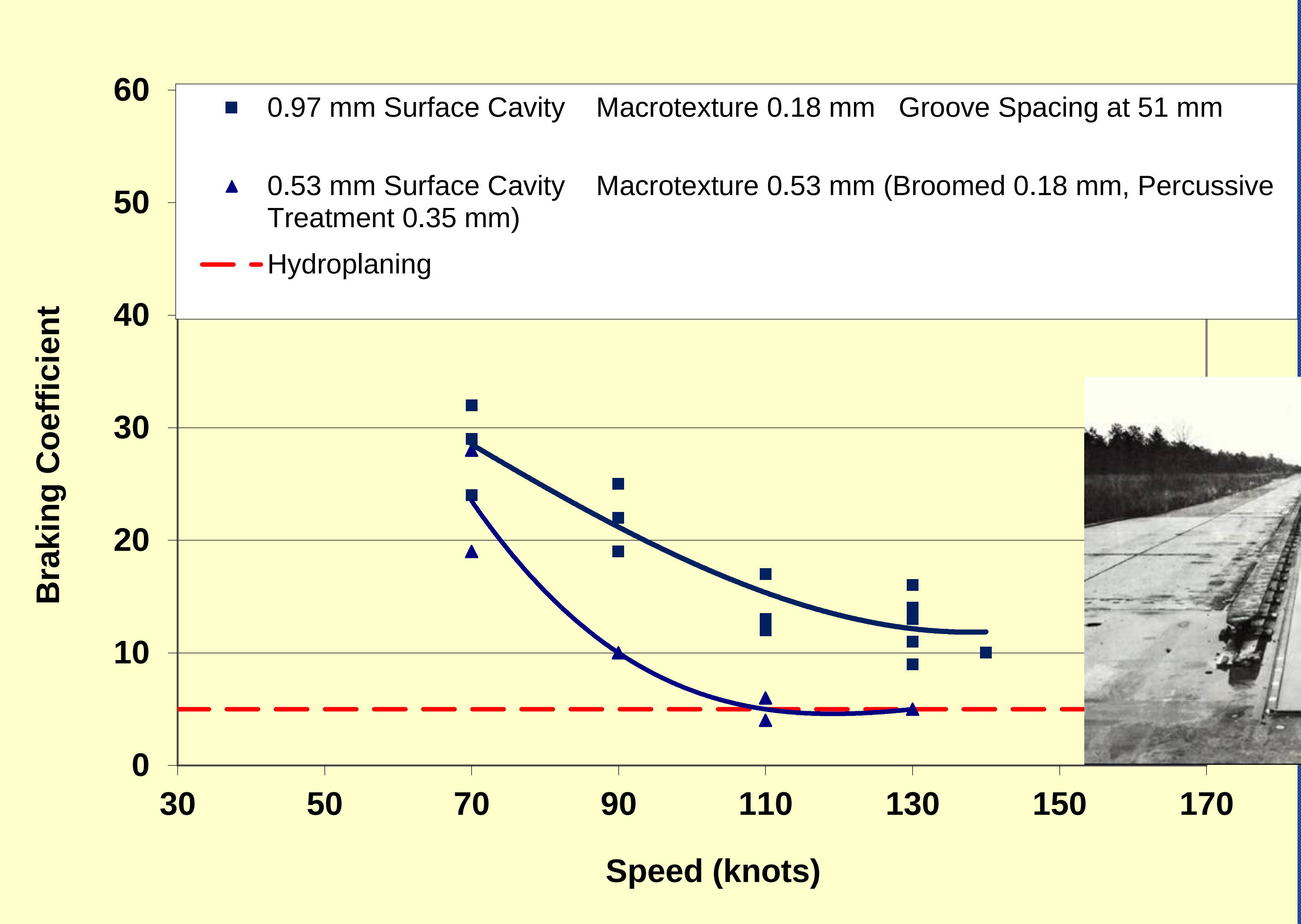
Grooving vs. Macrotexture
Worn Tire on a Wet PCC Pavement



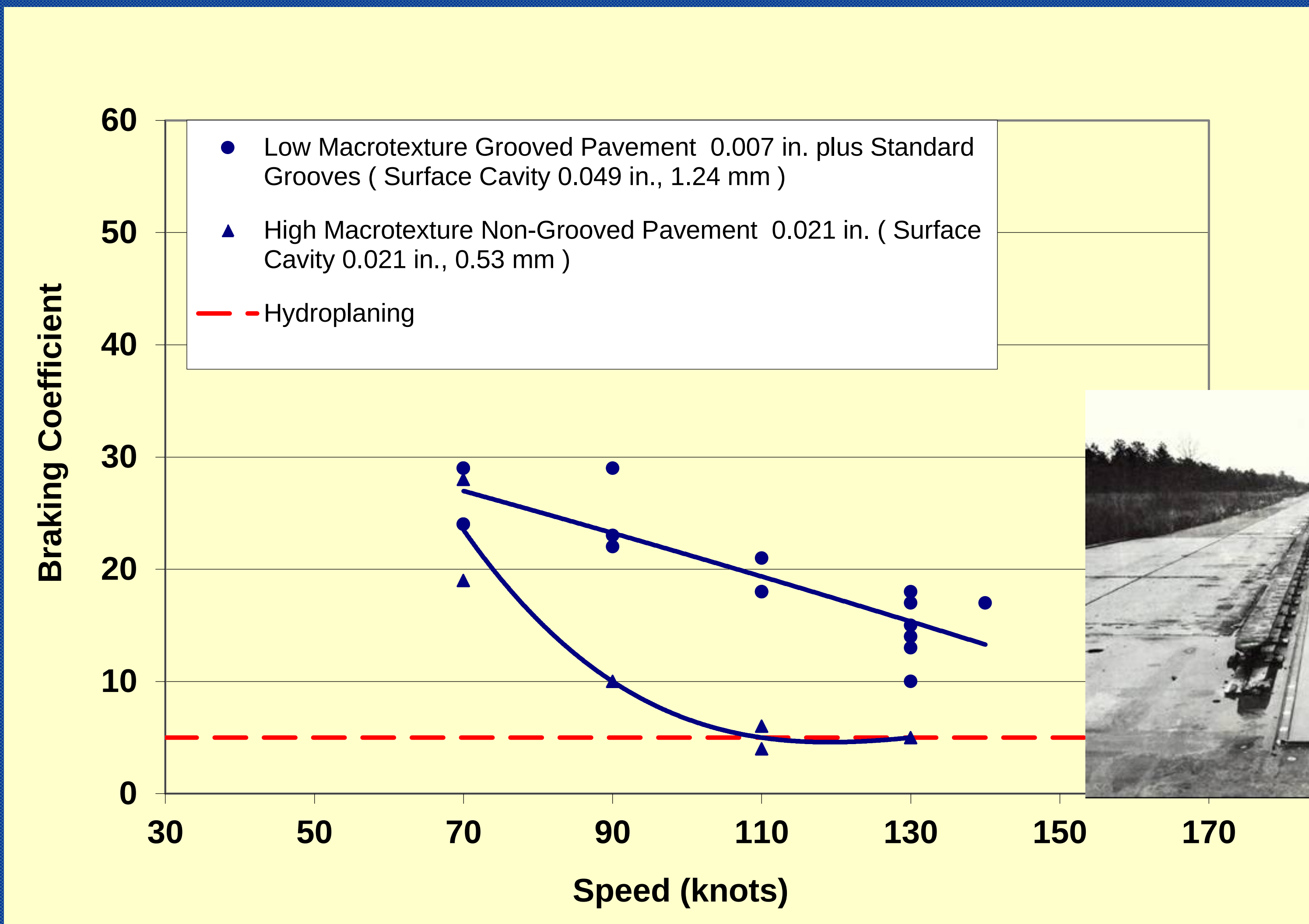
Grooving vs. Macrotexture
New Tire on a Puddled PCC Pavement

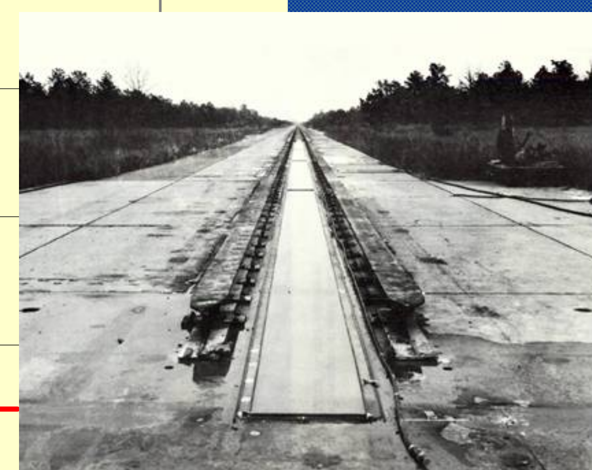


Grooving vs. Macrotexture
New Tire on a Puddled PCC Pavement



FAA Standard Groove Pattern vs. High Macrotexture New Tire on a Puddled PCC Pavement



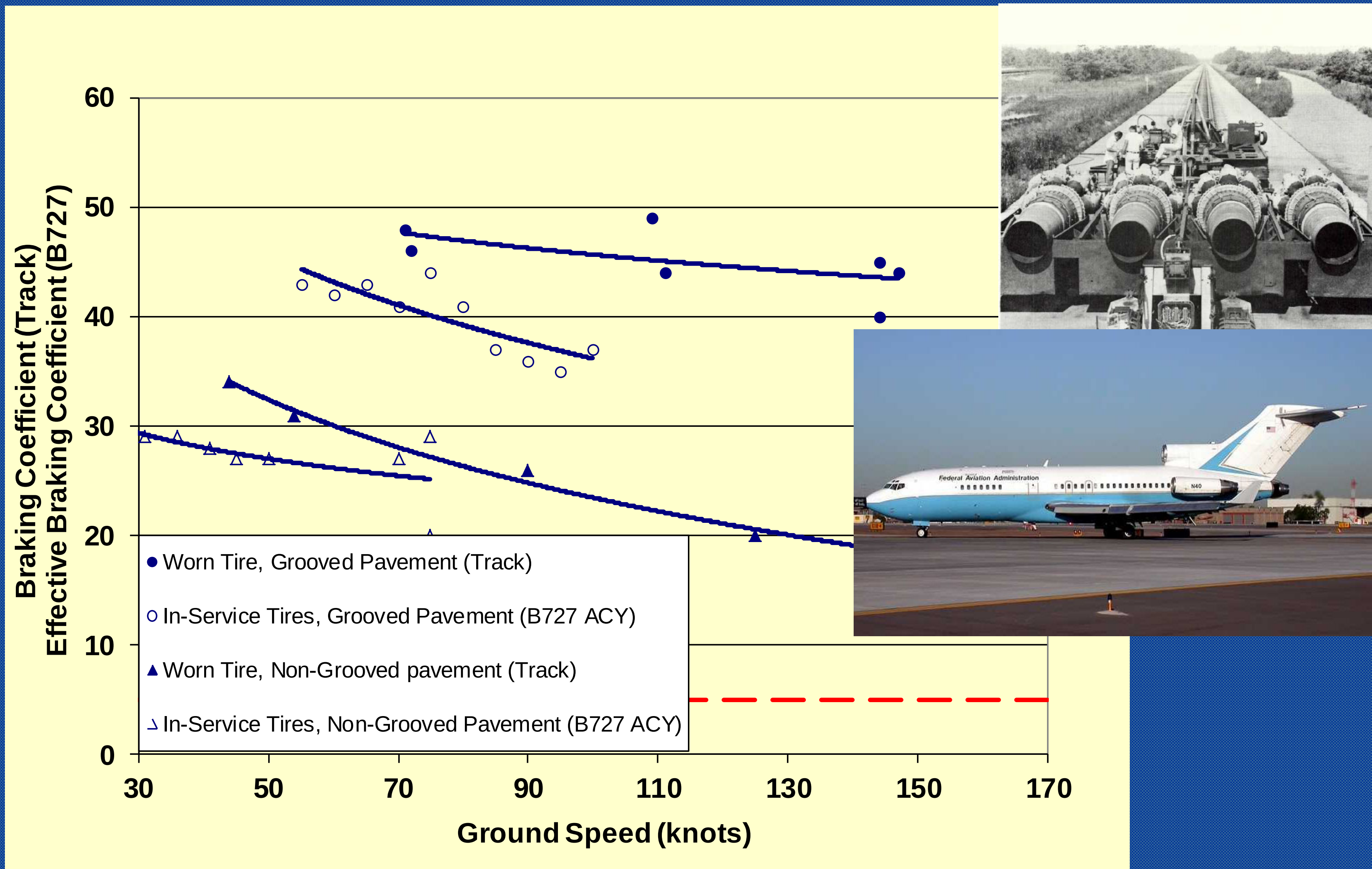


Landing of a Jet Transport Aircraft on a Stone Matrix Asphalt (SMA) Runway under Rainfall Conditions

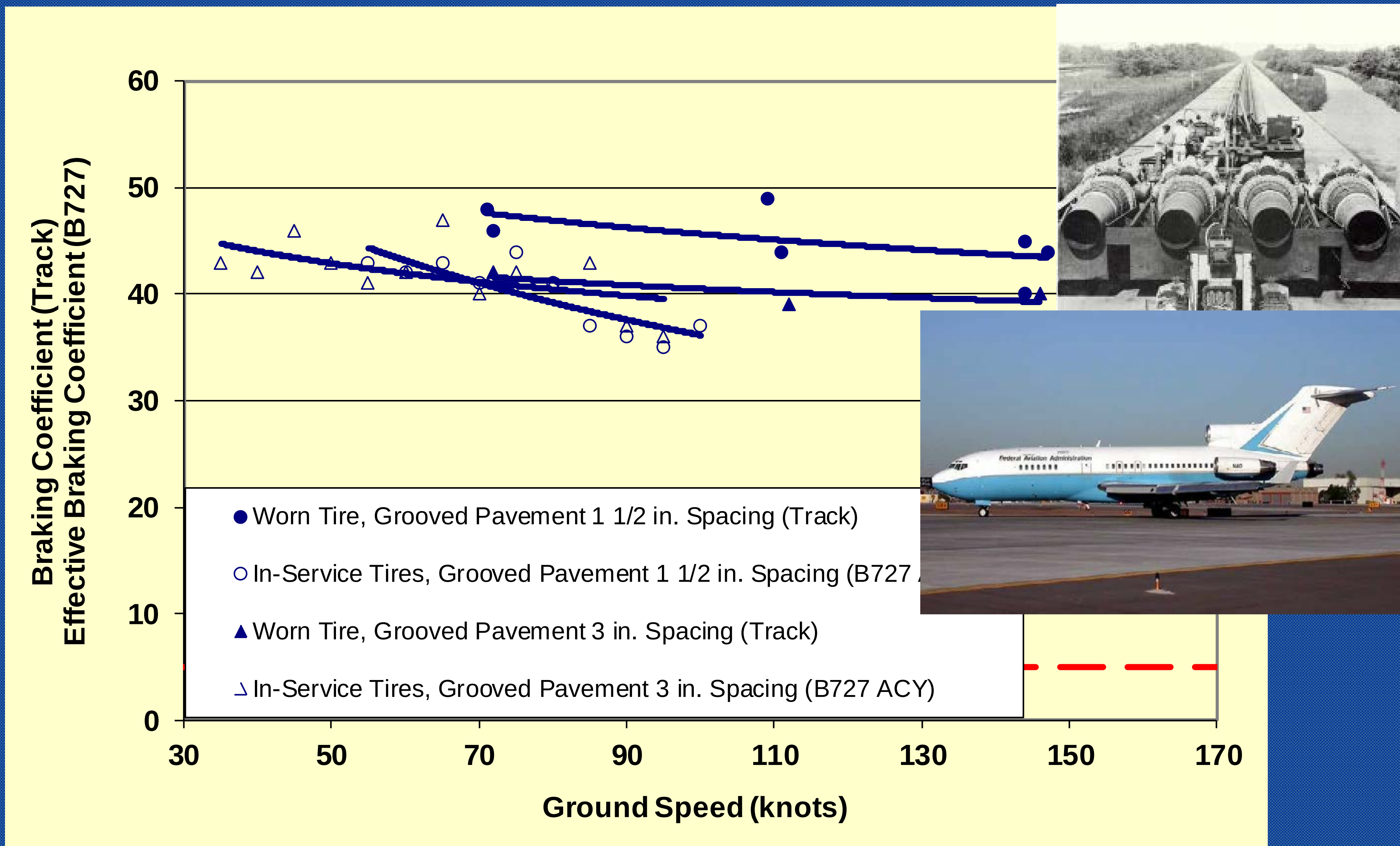
Takeoff of a Jet Transport Aircraft on a Stone Matrix Asphalt (SMA) Runway under Rainfall Conditions

Relationship between Results on the Test Track and Performance of the Aircraft on a Runway

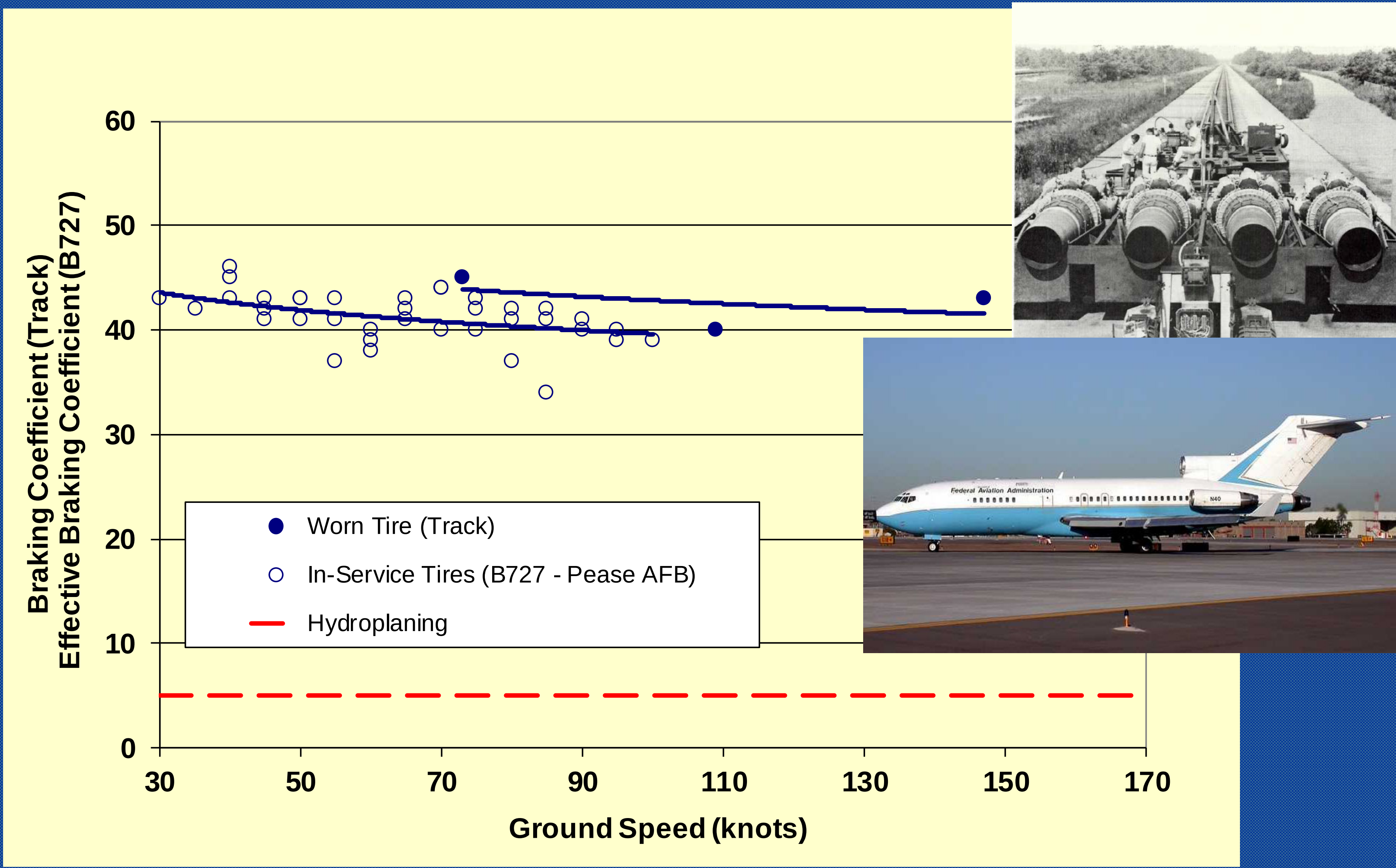
Braking on a Wet Asphalt Pavement



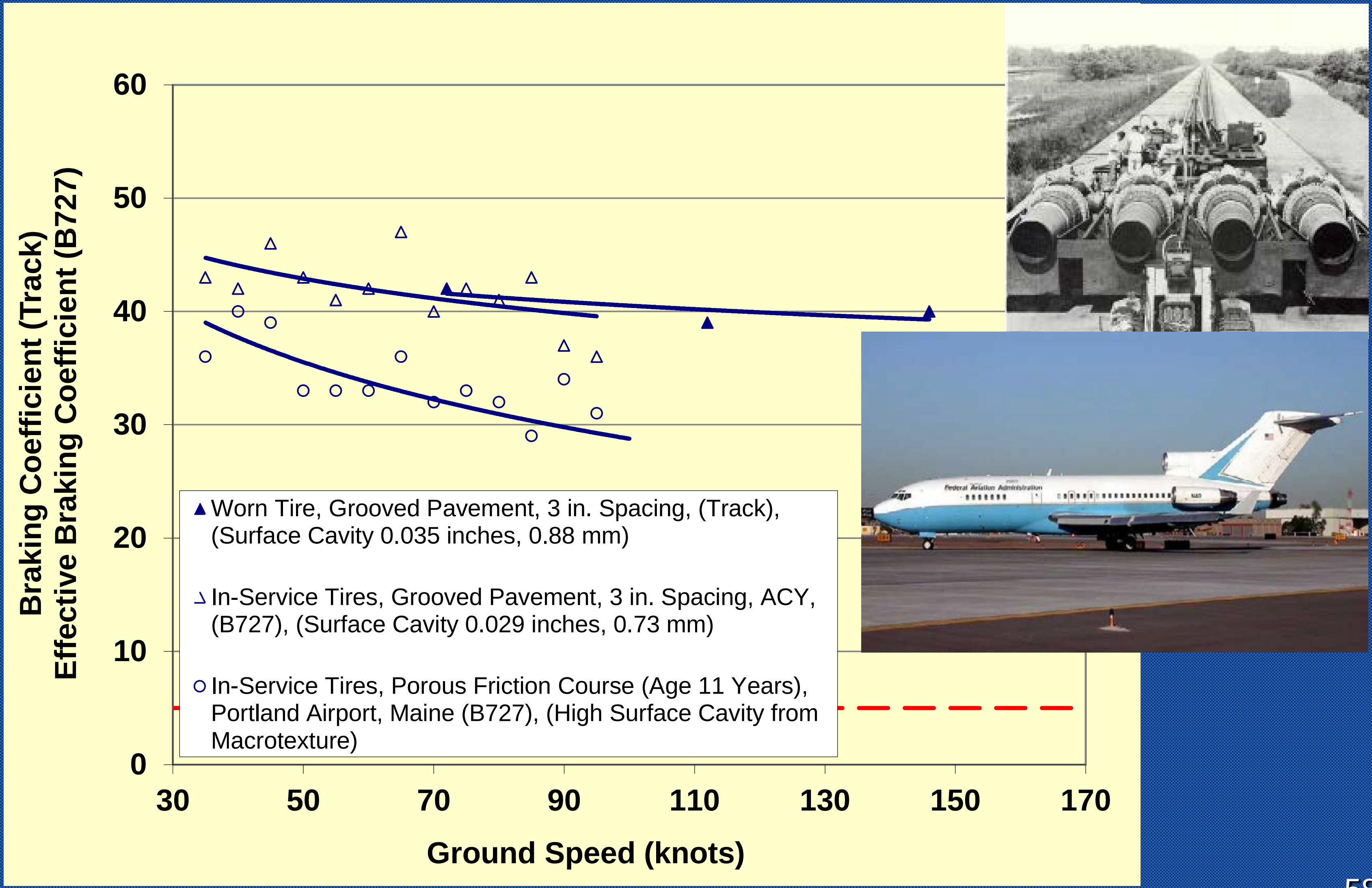
Braking on a Wet Asphalt Pavement



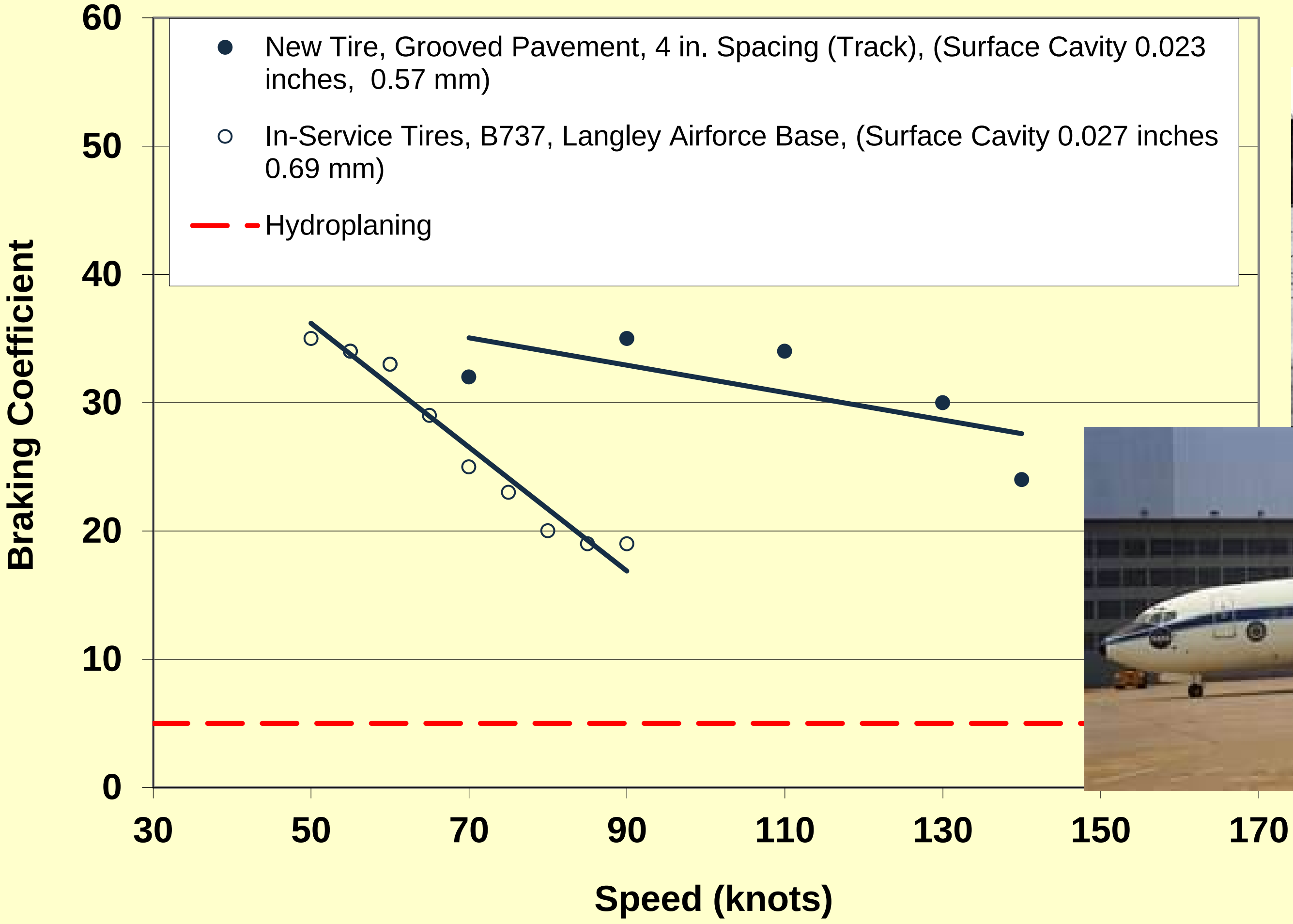
Braking on Wet Porous Friction Course



Grooving vs. Macrotexture Braking on Wet Asphalt Pavements



Grooving vs. Macrotexture Wet PCC Pavements



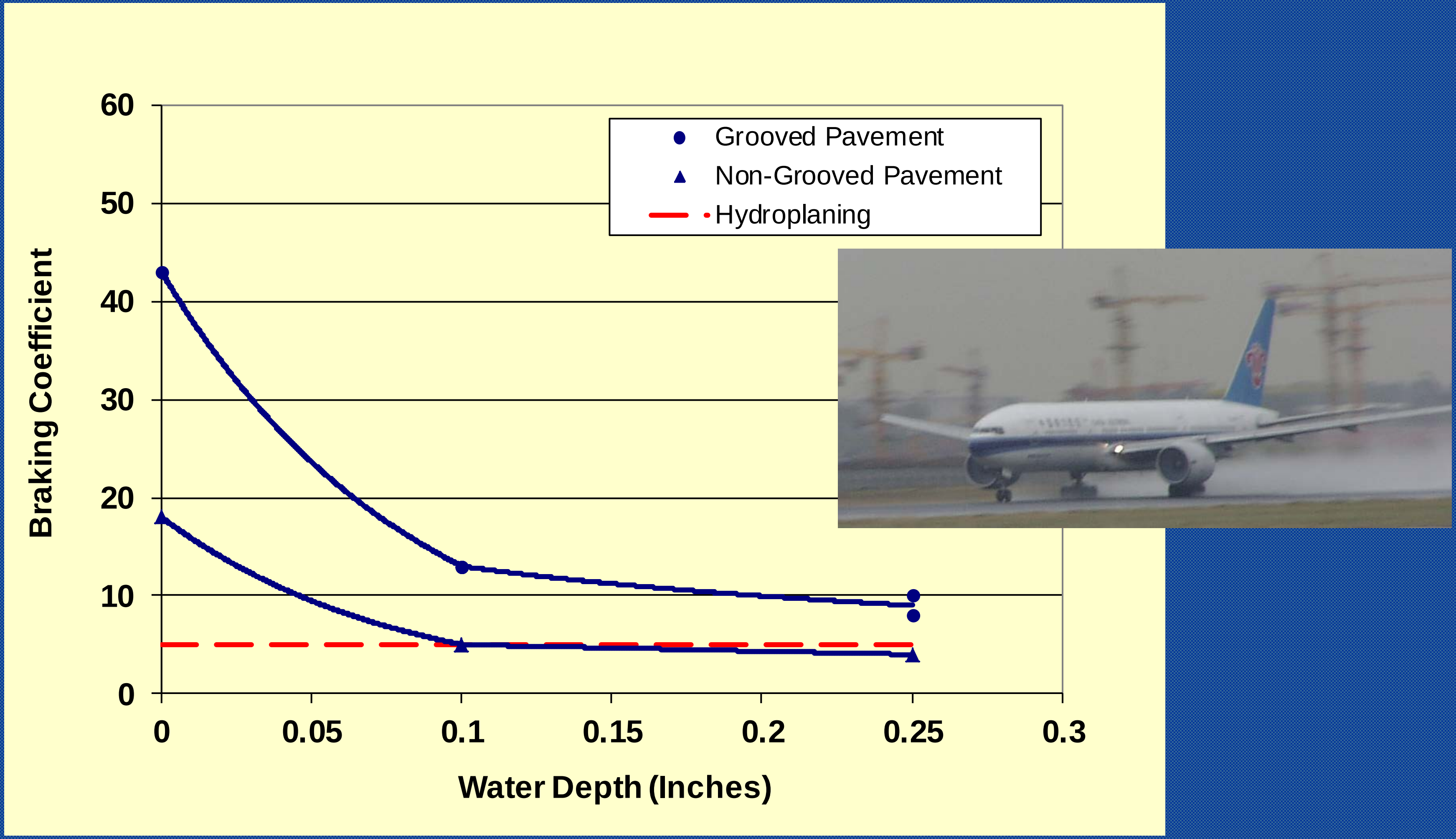
Dynamic Test Track Data Can Be Used to Simulate Tire-Pavement Interaction During the Landing and Takeoff of a Jet Transport Aircraft with Worn Tires on a Runway under Rainfall Conditions.

Inference Drawn from Simulation on Asphalt Pavement

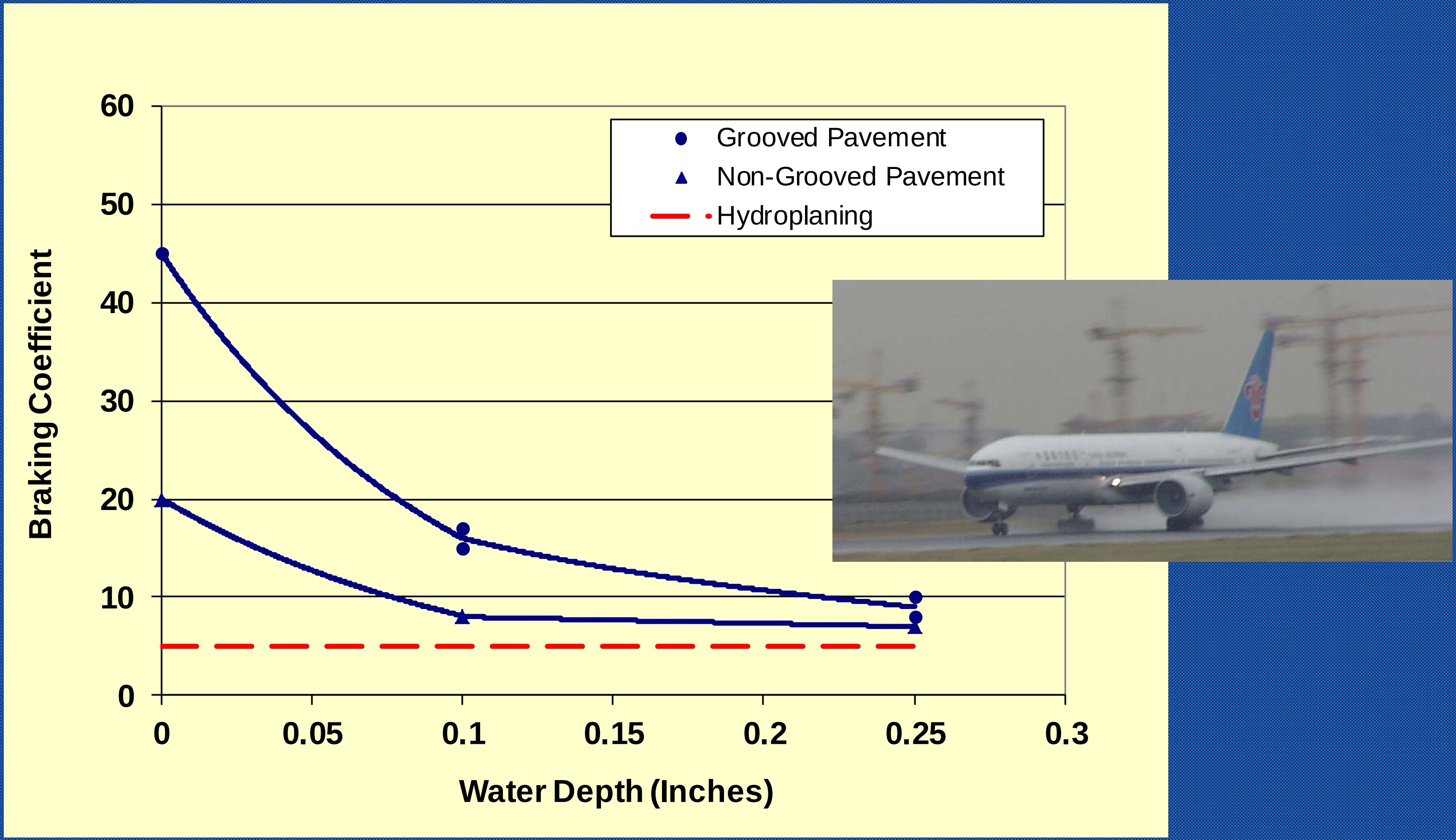
- Runway Grooving Offers the Potential to Double The Magnitude of Tire-Pavement Interaction for Jet Transport Aircraft Operating on Water Covered Runways.

Landing

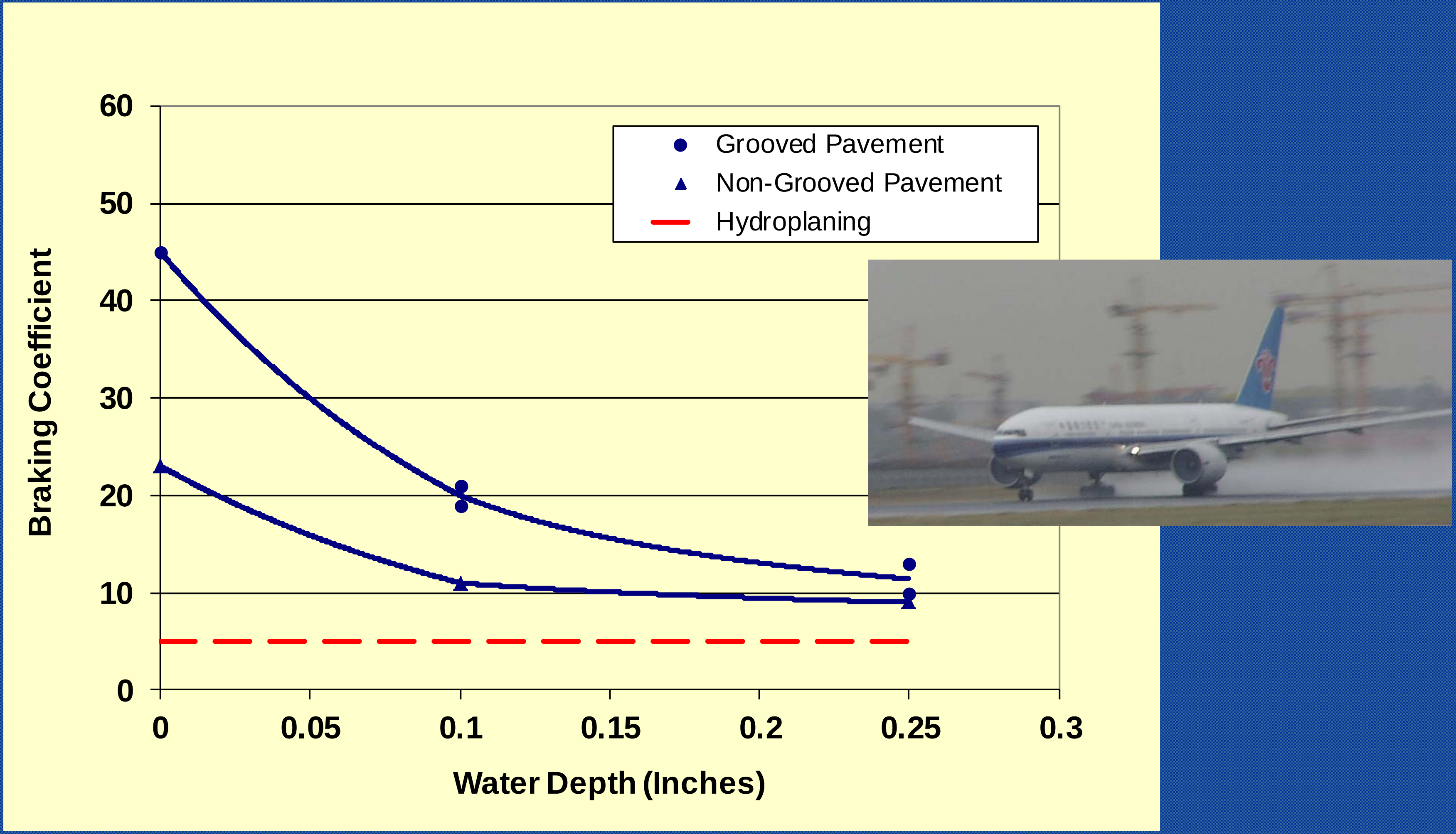
Fast Touchdown at 150 Knots



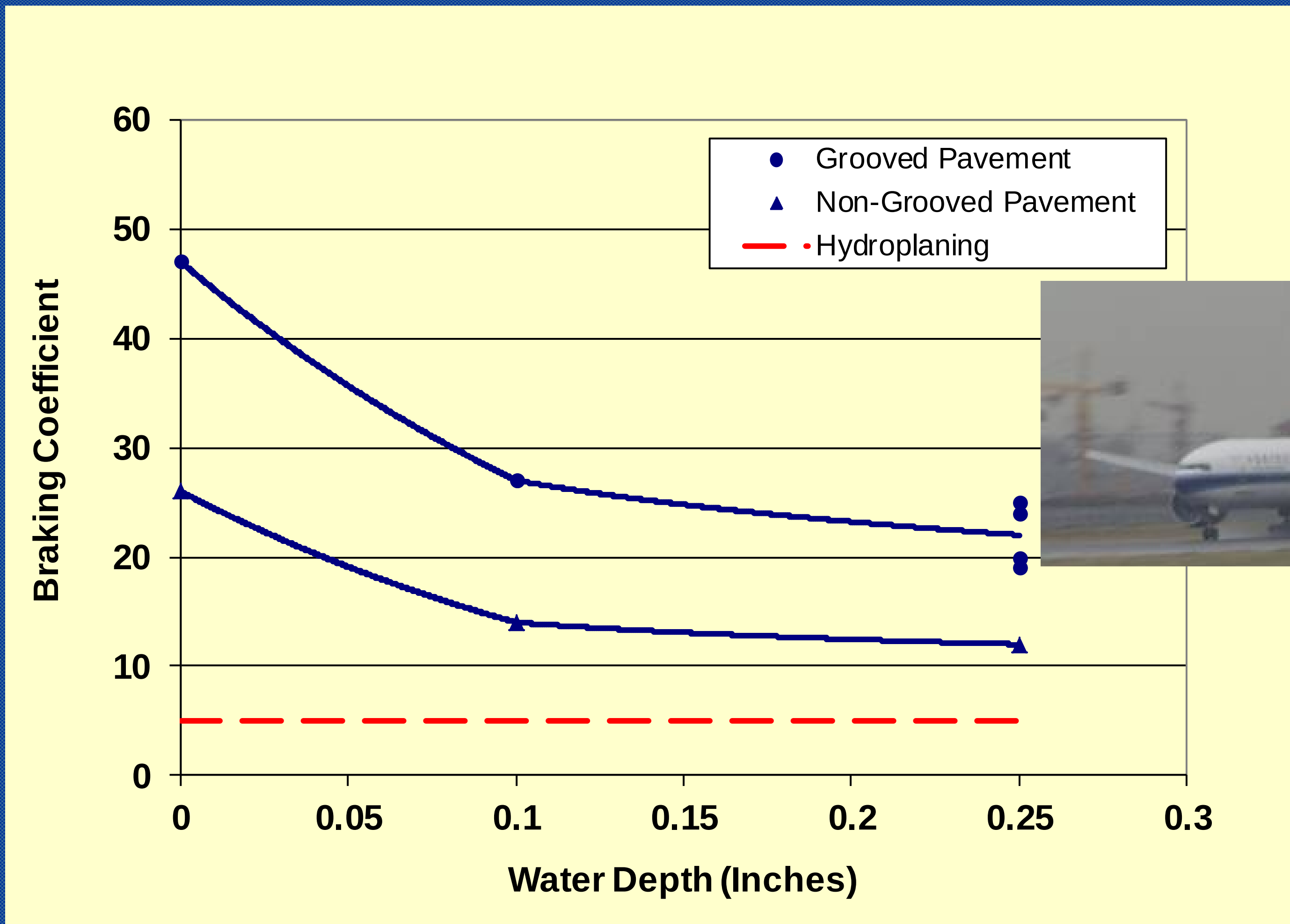
Touchdown at 130 Knots



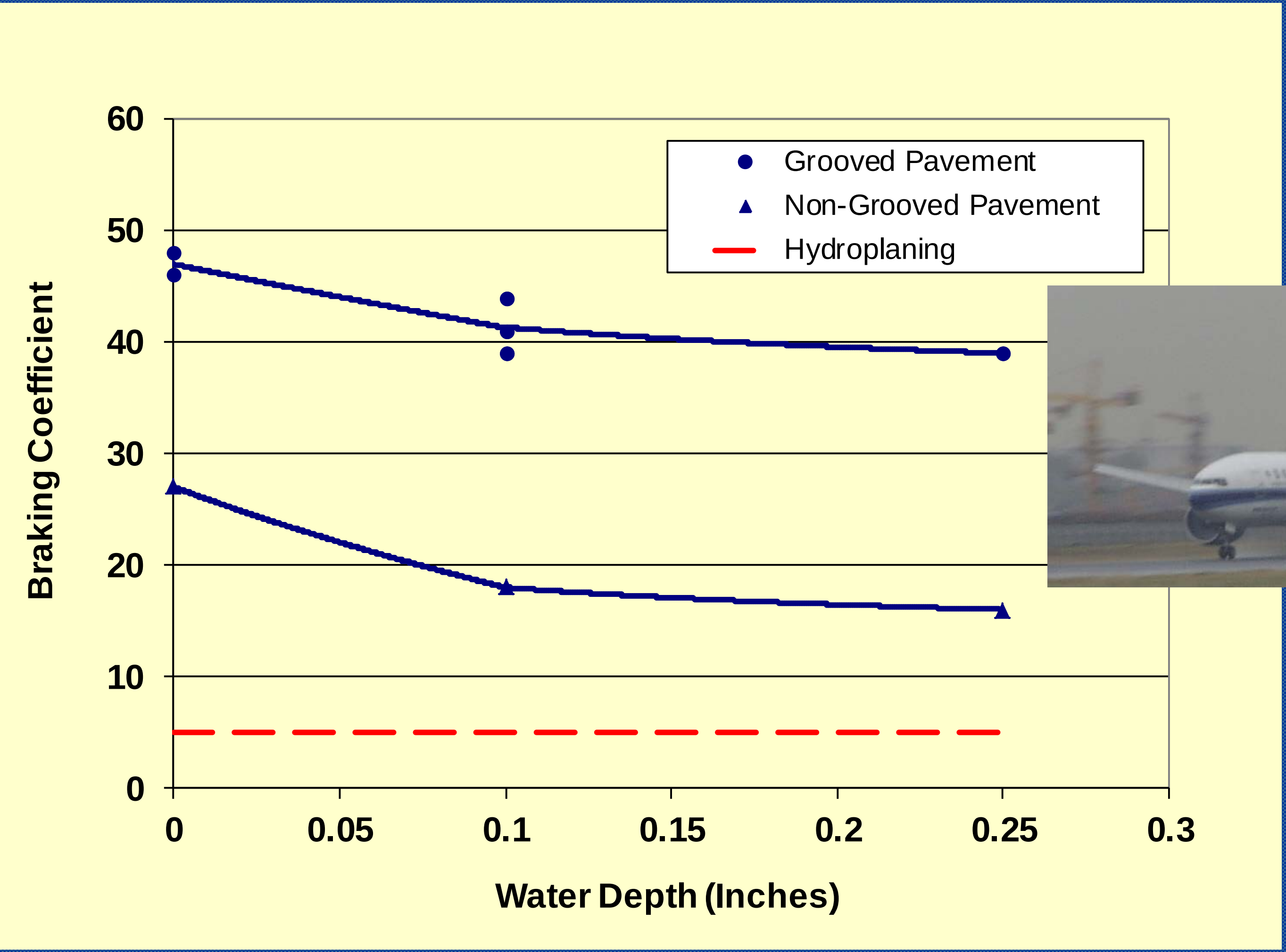
Braking at 110 Knots



Braking at 90 Knots

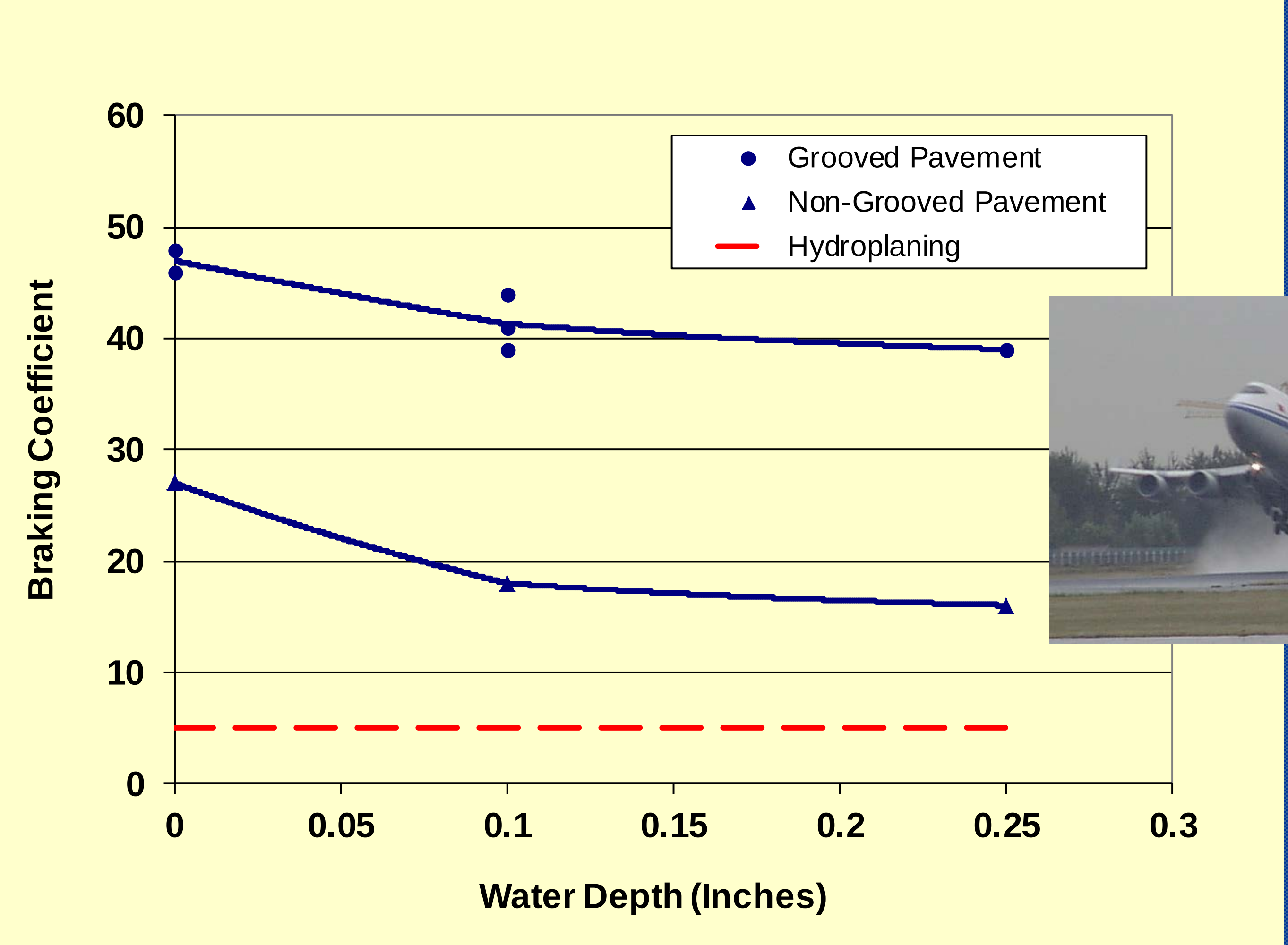


Braking at 70 Knots, Approaching High Speed Turnoff

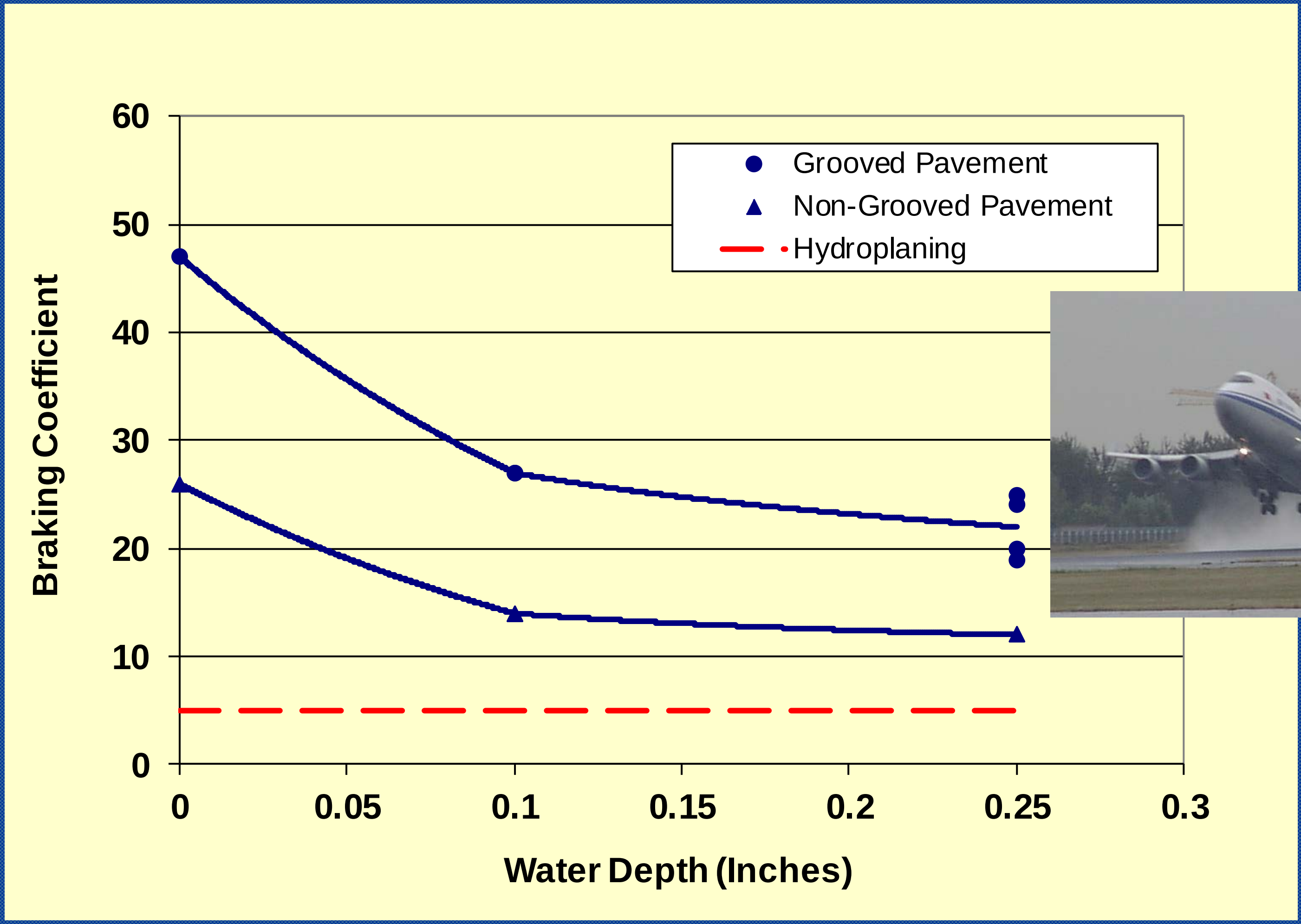


Takeoff

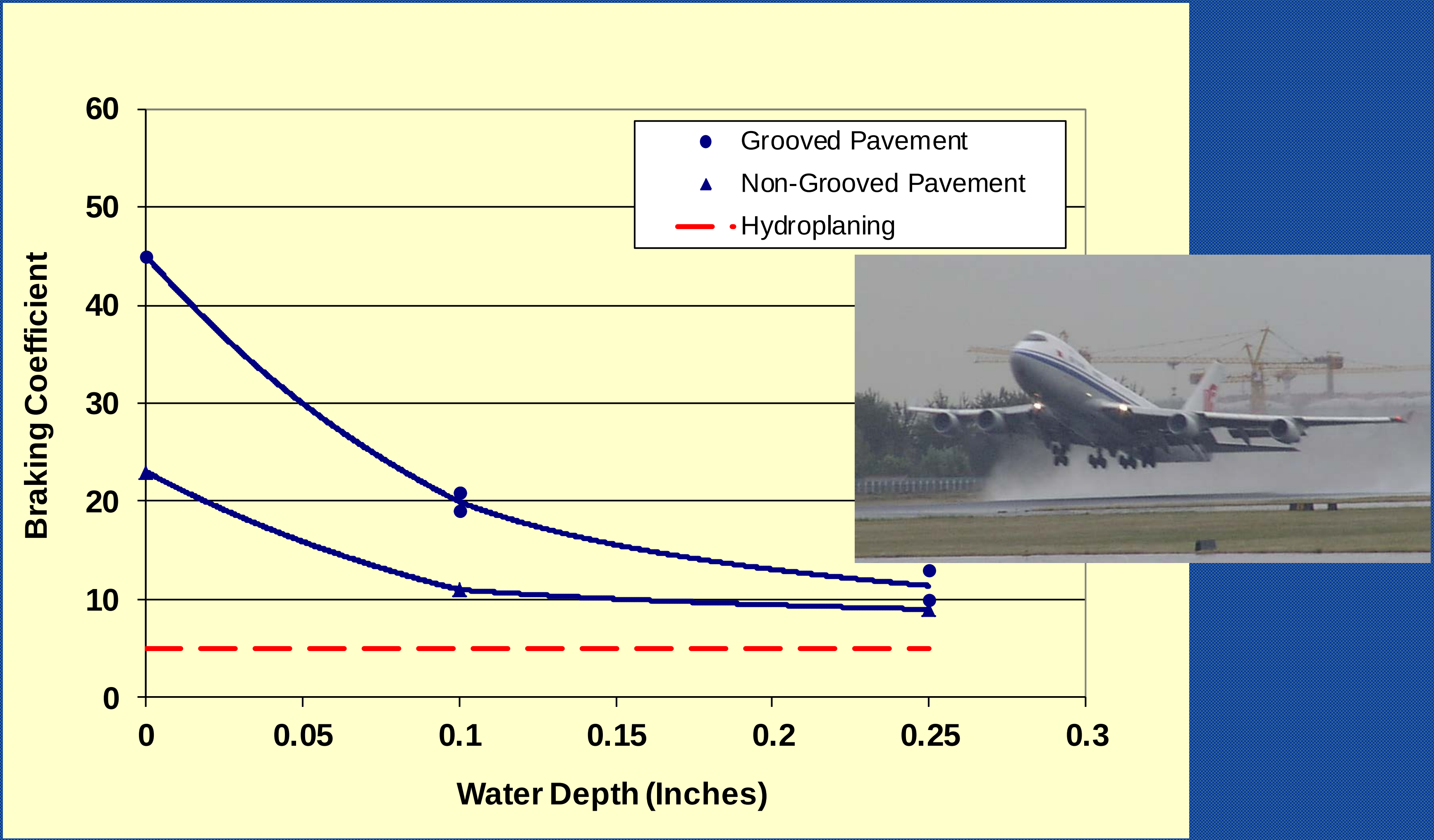
Takeoff Roll at 70 Knots



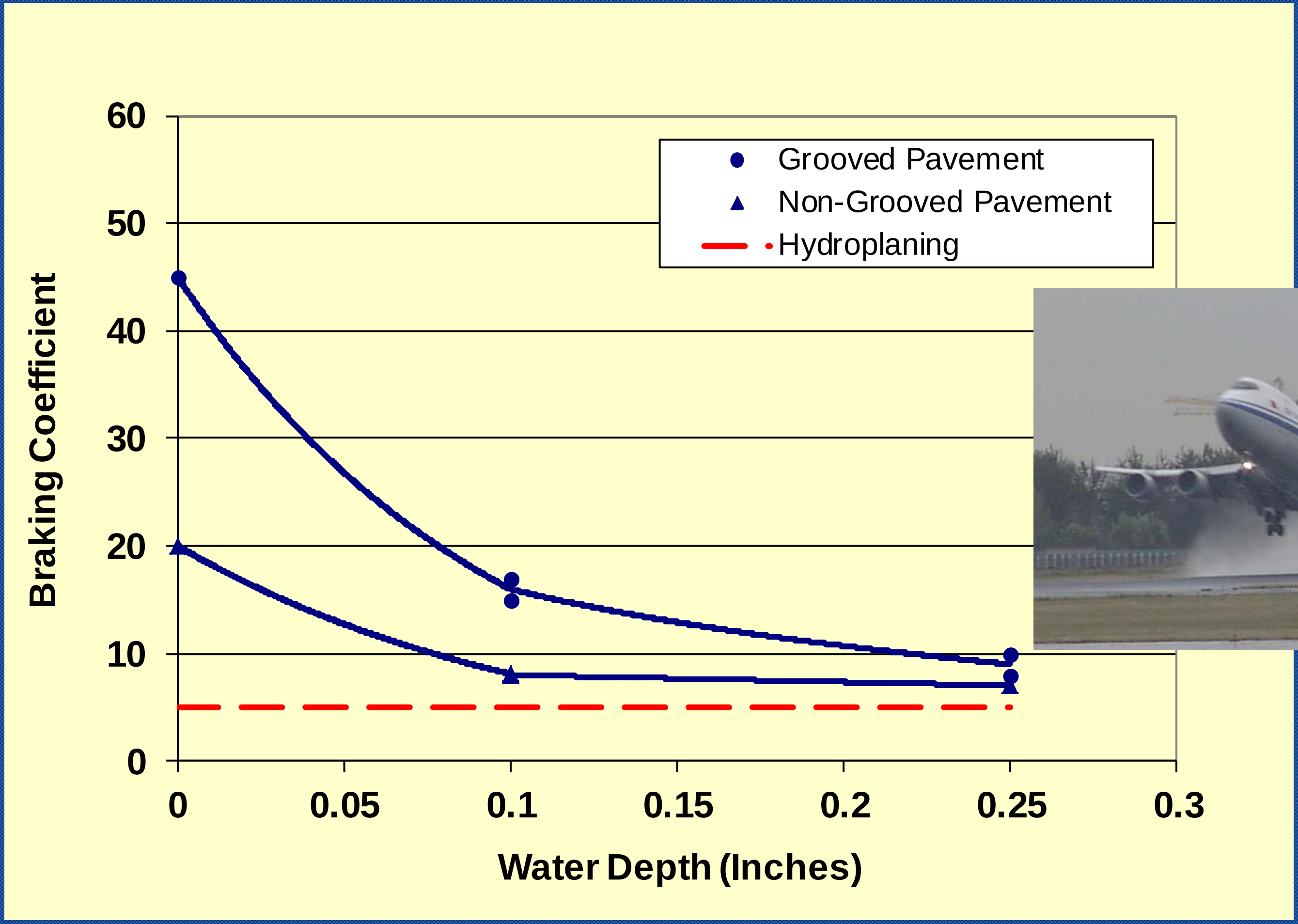
Takeoff Roll at 90 Knots



Takeoff Roll at 110 Knots



Decision Point at 130 Knots Takeoff or Abort



Summary

FAA Full Scale Test Program Braking/Hydroplaning Technical Advances Achieved

- Maximum Braking Data Base
- Asphalt as well as Portland Cement
- Porous Friction Course as well as Grooving
- Benefit of Grooving versus Tire Tread
- Uniformly Puddled Condition
- Groove Spacing up to 4 inches
- Speeds up to 150 Knots

FAA Full Scale Test Program Braking/Hydroplaning Products of the Effort

- Supports Current FAA Grooving Standards.
- Spacing of 1/4 x 1/4 in. Saw-Cut Grooves Extended from 1¼ ins. to 1½ ins.
- Grooving Costs Reduced by an Estimated 7%.
- More Significant Cost Savings Possible with Slightly Greater Increases in Spacing.

FAA Full Scale Test Program Braking/Hydroplaning Products of the Effort (Continued)

- Data Base Can Be Useful to Foreign Aviation Authorities in Supporting the Grooving of Runways in their Respective Countries.
- Data Base Can Support the Establishment of International Guidelines for the Grooving of Runways.

FAA Full Scale Test Program Braking/Hydroplaning

- Briefing and DOT/FAA Technical Reports Available for Download from NAPTF Website
- Google, Bing, or Yahoo
- faa naptf
- About the NAPTF
- Menu on left
- Located under "Downloads", "Safety"

Dynamic Test Track

- Naval Air Engineering Center (NAEC)
- Lakehurst, New Jersey
- High Speed Films of Tests Follow:

Double Click Here

Runway Grooving 2.wmv

FAA Governing Documents Covering Relevant Runway Surface Characteristics

- <u>Transverse</u> <u>Slope</u> Provides Drainage.
- <u>Texture</u> of Pavement Provides Friction.
- <u>Grooving</u> Enables Aircraft Tires to Contact the Pavement.

The Following Data Are Listed in this Presentation for Purposes of Continuity.

Reference Should Be Made Directly to the FAA Advisory Circulars When Actually Performing Work at an Airport.

FAA Governing Documents for Establishing Transverse Slope

- AC 150/5300 -13A Airport Design

  Transverse Slope 1% to 1.5%

- AC 150/537O -10F Standards for Specifying Construction of Airports

  Departure from Surface Design Plane

P-401 Asphalt	± 1/2 inch	(13 mm)
P-501 Portland Cement	± 1/4 inch	(6 mm)

FAA Governing Document for Surface Texture

- AC 150/532O -12C
  Measurement, Construction, and Maintenance of Skid-Resistant Airport Pavement Surfaces

Surface Texture

- Asphalt

  Hard, Angular Aggregates

  Resistant to Rounding and Polishing

- Portland Cement

  Surface Finish as Entrained with Fine Aggregate

Surface Texture Effectiveness

- Continuous Friction Measurement Equipment (CFME)
  - 8 Different Ones Are Listed
  - Either Self-Contained or Trailer
  - Operated at 40 and 60 Miles per Hour
  - Self- Watering to Effective Depth of 0.04 Inches (1 mm)
  - Friction Values are Recommended for New Construction and Maintenance

Example of a CFME

Friction Survey Frequency

TABLE 3-1. FRICTION SURVEY FREQUENCY

NUMBER OF DAILY MINIMUM TURBOJET AIRCRAFT LANDINGS PER RUNWAY END	MINIMUM FRICTION SURVEY FREQUENCY
LESS THAN 15	1 YEAR
16 TO 30	6 MONTHS
31 TO 90	3 MONTHS
91 TO 150	1 MONTH
151 TO 210	2 WEEKS
GREATER THAN 210	1 WEEK

Friction Level Classification

TABLE 3-2. FRICTION LEVEL CLASSIFICATION FOR RUNWAY PAVEMENT SURFACES

	40 mph			60 mph		
	Minimum	Maintenance Planning	New Design/ Construction	Minimum	Maintenance Planning	New Design/ Construction
Mu Meter	.42	.52	.72	.26	.38	.66
Dynatest Consulting, Inc. Runway Friction Tester	.50	.60	.82	.41	.54	.72
Airport Equipment Co. Skiddometer	.50	.60	.82	.34	.47	.74
Airport Surface Friction Tester	.50	.60	.82	.34	.47	.74
Airport Technology USA Safegate Friction Tester	.50	.60	.82	.34	.47	.74
Findlay, Irvine, Ltd. Griptester Friction Meter	.43	.53	.74	.24	.36	.64
Tatra Friction Tester	.48	.57	.76	.42	.52	.67
Norsemeter RUNAR (operated at fixed 16% slip)	.45	.52	.69	.32	.42	.63

Surface Texture Degradation

- Rubber Deposits
- Wear and Polish
- Weather Erosion

Corrective Measures Are Discussed.

Grease Smear Test Can Be Taken at Any Time to Determine the Surface Macrotexture.

Rubber Deposit Removal Frequency

TABLE 4-1. RUBBER DEPOSIT REMOVAL FREQUENCY

NUMBER OR DAILY TURBOJET AIRCRAFT LANDING PER RUNWAY END	SUGGESTED RUBBER DEPOSIT REMOVAL FREQUENCY
LESS THAN 15	2 YEARS
16 TO 30	1 YEAR
31 TO 90	6 MONTHS
91 TO 150	4 MONTHS
151 TO 210	3 MONTHS
GREATER THAN 210	2 MONTHS

Note: Each runway end should be evaluated separately, e.g. Runway 18 and Runway 36.

CFME Workshops

- NASA

  Annual Runway Friction Workshop

  Wallops Island, Virginia

- Penn State

  Annual Runway Friction Workshop

- International Friction Pavement Association (IFPA)
- Transport Canada

  Correlation of CFME at LCPC, Nantes, France

FAA Governing Document for Groove Placement

- AC 150/537O -10F
  Standards for Specifying Construction of Airports

  P-621
  Saw-Cut Grooves

Time Frames Associated with Grooving

- Curing of Pavements Prior to Grooving

  Asphalt 30 Days

  Portland Cement Concrete 28 Days

  Can be Decreased at the Discretion of the Engineer.
- Grooving Operation

  1 to 2 Weeks

Grooving Machine

Cutting Blades Mounted on Arbor

Tolerances for Each Day's Production by a Machine

- Alignment
  ± 1 1/2 in. in 75 ft. (± 38 mm in 23 meters)
- Groove Dimensions

Depth: 90% or more at least 3/16 in. (4.75 mm)
60% or more at least 1/4 in. (6 mm)
Not more than 10% to exceed 5/16 in. (8 mm)

Width: Same Tolerances

Tolerances for Each Day's Production by a Machine (Cont'd)

- Center-to-Center Spacing

Standard	1 1/2 in.	(38 mm)
Minimum	1 3/8 in.	(35 mm)
Maximum	1 1/2 in.	(38 mm)

- Grooves Can Be Terminated Within 10 ft. (3 Meters) of the Pavement Edge.

Daily Acceptance Testing

- Depth, Width, and Spacing
- Each of 5 Zones Across Pavement Width
- 5 Consecutive Grooves
- Each Arbor on Each Machine
- 3 Times per Day
- Adjustments When More Than 1 Groove On an Arbor Fails to Meet Depth, Width, or Spacing in More Than 1 Zone

FAA Governing Document for Grooving Maintenance

- AC 150/532O -12C
  Measurement, Construction, and Maintenance of Skid-Resistant Airport Pavement Surfaces

Grooving Degradation Limits

- Groove Dimensions

  Depth: 40% of Grooves are 1/8 inch (3.18 mm) or Less for a Longitudinal Runway Distance of 1,500 ft. (457 Meters)

  Width: Same Limits

A Grooved Runway is a Safer Runway