



BY DAVID THOMAS

# Can You STOP?

A Norwegian study found that runway condition reports may not provide an answer.

There was no correlation between aircraft braking coefficient<sup>1</sup> and the measured or estimated runway friction coefficient<sup>2</sup> in 30 Norwegian runway accidents and incidents over the past 10 years, a study has shown. The report on events on contaminated and slippery runways was published by the Accident Investigation Board Norway (AIBN).<sup>3</sup>

The report discusses a number of factors that likely influence the mismatch between aircraft braking coefficients and runway friction

coefficients, including regulatory climate, limitations of friction measurements, meteorology, runway treatment and operational aspects.

The report indicates that in the majority of the 30 accidents and incidents, the stakeholders involved were simply not aware that some of the existing rules and regulations are dated and based on simplifications of the actual physical conditions.

Many of Norway's airports are coastal, with terrain in the vicinity

that, when combined with windy conditions and the frequent frost-thaw winter climate, provides a challenging environment for aircraft operations. The report indicates that the increased risk involved in winter operations is not necessarily assessed or managed effectively.

Joint Aviation Requirements—Operations (JAR-OPS) 1.490 states that when operations on contaminated runways are not limited to rare occasions, operators should provide additional

measures to ensure an “equivalent level of safety.”<sup>4</sup> The AIBN report reveals that this equivalent level of safety, which likely means an equivalent to summer conditions, is not achieved in Norway. Likewise, the report says that the Norwegian Civil Aviation Authority (CAA) apparently lacks an overall risk assessment for winter operations.

### No Correlation

While aircraft manufacturers use different performance values and models to determine braking performance for landing on contaminated runways, they all acknowledge that there is no correlation between runway friction measurements and aircraft braking performance.

The AIBN report notes, however, that airline and airport operators continue to use runway friction measurements as primary data in determining aircraft braking performance. Some Norwegian airlines have even developed or adopted correlation curves combining aircraft braking coefficients and runway friction coefficients (Figure 1). This may not be that surprising considering the International Civil Aviation Organization (ICAO) SNOWTAM (snow notice to airmen) table shows friction values that correspond to estimated braking action. Likewise, a number of modern laptop performance tools have an option for friction coefficient input.

The AIBN has demonstrated that none of the approved friction measuring devices are reliable and that friction values, reported to two decimal places according to ICAO standards, may vary greatly depending on surface temperature and moisture (Figure 2). In dry conditions, the uncertainty is in the order of +/- 0.10; in moist or wet conditions, it is up to +/- 0.20. The report suggests that when a runway is covered with moist or wet

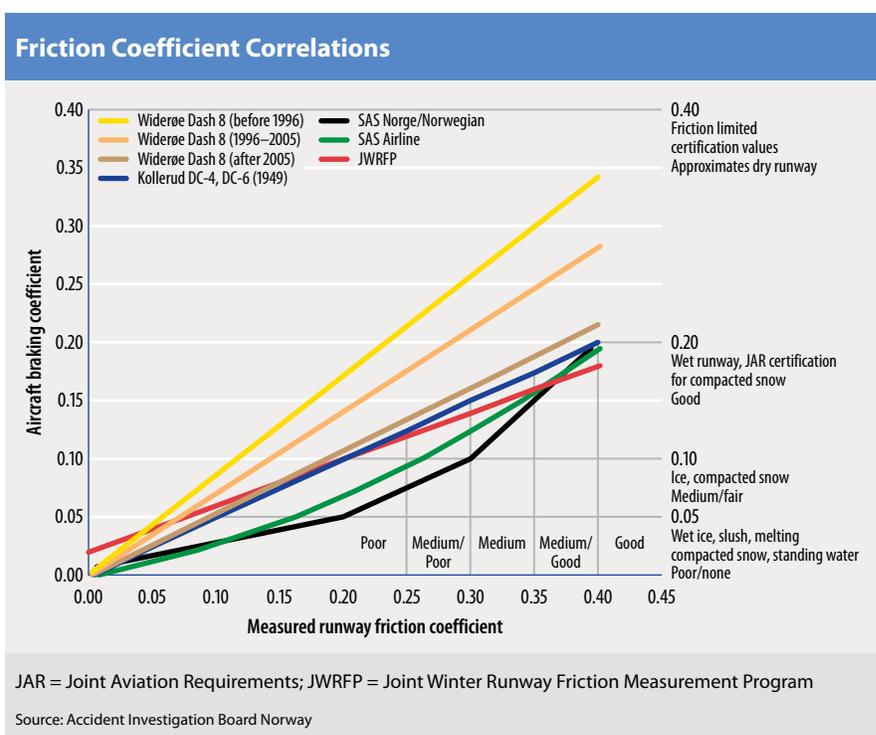


Figure 1

### Variables Affecting Friction Values

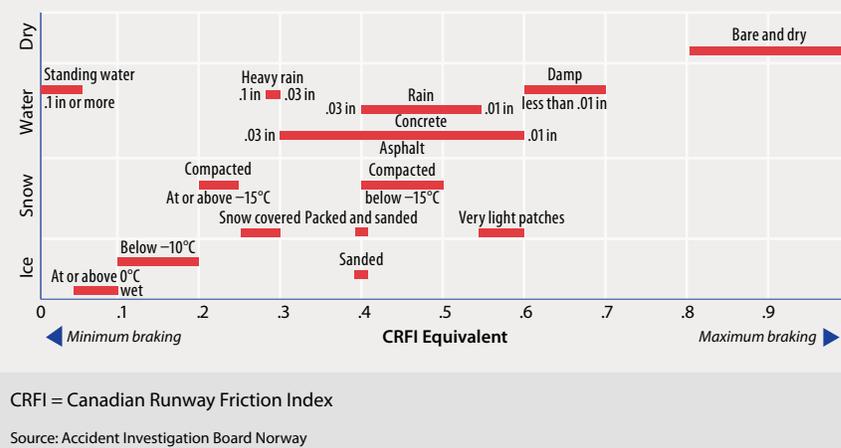


Figure 2

contaminants, a braking action of “poor” should be reported.

### Kelvin Spread

In 21 of the 30 accidents and incidents, the spread between air temperature (measured at a height of 2 m above the runway surface) and dew point was 3

degrees C or less. This finding led the AIBN to develop the “3-Kelvin-Spread Rule,” which states that at temperatures of 3 degrees C and below, with a temperature/dew point spread of 3 degrees C or less, a runway contaminated by snow or ice may be more slippery than anticipated (see p. 16).

The narrow temperature/dew point spread indicates that the air mass is close to saturation, which is often associated with precipitation or fog.

The validity of the rule may depend on its correlation with precipitation, but it may also, at least in part, depend on the exchange of water at the air-ice interface. Due to the other variables involved — such as surface temperature, solar heating and ground cooling or heating — a small temperature/dew point spread does not always mean that the braking action will be poor. The report says that the rule may be used as an indicator of slippery conditions but not as an absolute. When these conditions exist, it may be appropriate to factor the landing distance further.

### Crosswind Guidelines

Of the 30 accidents and incidents, 19 involved crosswinds, which, when combined with a runway with reduced friction and/or only a partially cleared width, impose further limits on aircraft operations. The report stresses that crosswinds remain a major factor when considering directional control on contaminated runways.

The report notes that the operational documentation provided by manufacturers may include recommended crosswind guidelines for contaminated runways. The guidelines are based on analytical computations and simulations; they assume uniform runway surface conditions, steady wind components, an evaluation of what the average line pilot can be expected to handle and a conservative assumption of an aft center of gravity.

However, the guidelines have not been demonstrated as part of the certification process. The AIBN has found that airlines often develop their own crosswind limits, which, although

they may be approved by the regulator, might be optimistic. The report cites the Transport Canada table of crosswind versus friction values as a more conservative tool for operators to consider when developing crosswind guidance.<sup>5</sup>

### Surface Treatments

Chemicals and sand are used in Norway during winter to increase runway friction. Chemicals are used as deicing agents to melt residues of snow and ice after the runway has been cleared by mechanical devices such as brushes, plows and snow blowers. The chemicals also are intended to serve as anti-icing agents.

The report says, however, that water resulting from melting or precipitation may dilute the chemicals, which in turn could lead to further freezing and the formation of “black ice.” Likewise, when the chemicals dry, a viscous, slippery film may form.

When chemicals have been used, the runway is likely to be reported as “wet,” although the runway friction may be less than anticipated for a wet runway.

The AIBN has found that sanding, which has been used for many years to treat contaminated runways, is most effective in low temperatures and dry weather conditions, while on wet ice or loose contamination — that is, wet or dry snow and slush — the effects are minimal.

### Data Limitations

Data for landing performance on contaminated runways are published either as advisory information in the quick reference handbook or as theoretical certified (i.e., not demonstrated) data in the aircraft flight manual.

Traditionally, contaminated performance data have been based on analytical computations using aerodynamic and engine parameters demonstrated

in flight tests, and on an assumed wheel braking model for the runway effect. Consequently, the contaminated runway data may not always represent the performance that will be achieved, and additional safety margins should be considered, the report says.

AIBN analysis indicates that reverse thrust accounts for approximately 20 percent of the total braking force on a contaminated runway. Under European Union operations regulations, a credit for reverse thrust is allowed when dispatching to a contaminated runway. The report acknowledges that reverse thrust often contributes significantly to an aircraft’s deceleration on a contaminated runway but says it may be optimistic to allow for the credit, given that EU-OPS 1.485 requires an engine failure to be considered for all flight phases. Clearly, if an engine failure were to occur during the landing phase, one less reverser would be available; hence, there would be less reverse thrust available to aid deceleration. Moreover, late or incorrect selection of reverse thrust has been a significant contributory factor in a number of excursions on contaminated runways.

In an example of how safety factors can be reduced on contaminated runways, the report notes that while reverse thrust definitely aids braking performance on a dry runway, any *degradation* of reverse thrust may significantly reduce braking performance on a contaminated runway.

### Improvements at Hand

The report also discusses the limitations of the current tools used to produce runway surface condition reports, the lack of standardization and the subjectivity involved. These issues are exacerbated by flight crews who make

decisions about landing performance based on their belief that the reports are the result of accurate scientific evaluation. However, the report says that these limitations and misconceptions may be eliminated with the development of new technology and a re-evaluation of landing performance.

The Integrated Runway Information System (IRIS), a Norwegian project initiated in 2008, has as its primary objective the assessment, prediction and communication of accurate braking action information to flight crews.

The project has collected substantial meteorological and runway surface condition data along with flight data on aircraft braking coefficients (Figure 3). This information has been, and continues to be, analyzed in order to develop a link among prevailing weather conditions, runway surface condition and actual aircraft braking action. The project has received valuable input from Boeing and considerable interest from a number of Norwegian airlines, the Norwegian CAA and the AIBN.

After the Chicago Midway runway excursion (ASW, 2/08, p. 28), the U.S. Federal Aviation Administration (FAA) started work in response to findings by the U.S. National Transportation Safety Board that the guidance and regulation related to contaminated runway operations are insufficient. The FAA chartered the Takeoff and Landing Performance Assessment Aviation Rule-making Committee (TALPA ARC).

The committee, which completed its work in November 2009, developed the Paved Runway Condition Assessment Table. The table, commonly called the *matrix*, enables airport personnel to categorize runway surface conditions as standard codes that can be provided to pilots in a standardized format and used for contaminated landing performance calculations (ASW, 11/10, p. 33). The FAA currently is conducting trials of the matrix with several airlines at several airports in the United States.

Manufacturers have started to change their performance values and models to align with the matrix and are developing

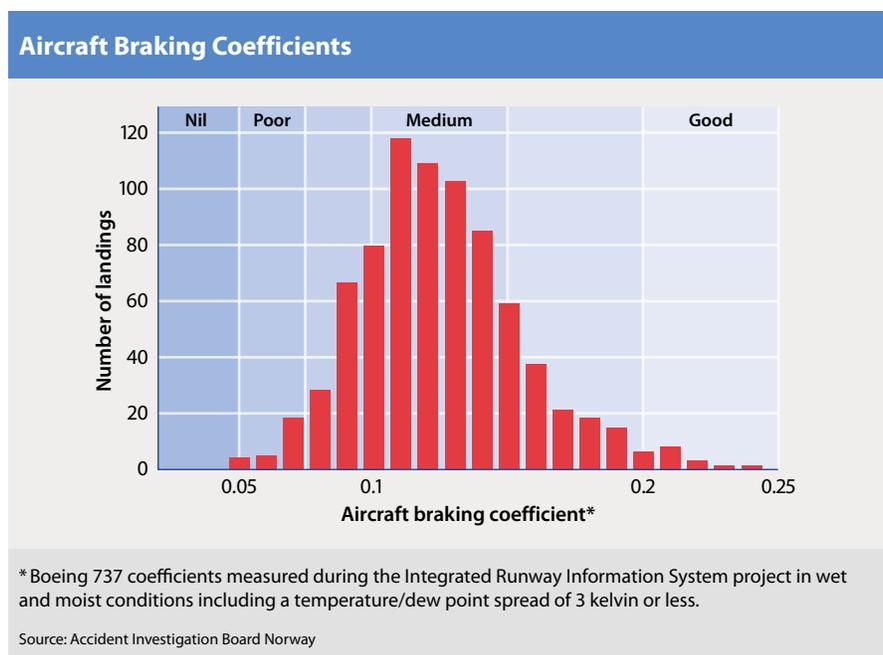
*operational landing distances* for in-flight landing performance calculations with consideration given to actual meteorological and runway surface conditions. Operational landing distances reflect the performance that a line pilot may achieve without any additional safety margin, allowing for seven seconds' air distance between crossing the threshold and touching down at 96 percent of the approach speed. Traditionally, actual landing distances have been based on a touchdown speed of 93 percent of the approach speed and may not have been representative of normal flight operations.

The AIBN believes that the work performed by the TALPA ARC and IRIS will lead to accurate runway surface condition reporting. ➤

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## Notes

1. *Aircraft braking coefficient* is defined by Boeing as the ratio between the aircraft's braking force and its weight. For example, the coefficient for an aircraft creating 20,000 lb of braking force and weighing 100,000 lb is 0.20. Airbus uses the term *effective friction coefficient* to define the available friction between a braked wheel and the runway surface. Although the values are similar, effective friction coefficients tend to be larger than aircraft braking coefficients for the same type of surface contaminant.
2. *Runway friction coefficient*, or the ratio of forces between an aircraft's tires and the runway surface, is generated by friction-measuring devices.
3. AIBN Report SL 2011/10. *Winter Operations, Friction Measurements and Conditions for Friction Predictions*. May 2011.
4. This provision has been proposed for inclusion in the new European Union aircraft operations regulations.
5. Transport Canada. *Aeronautical Information Manual*. TP 14371. Part 1.6, "Canadian Runway Friction Index."



**Figure 3**