Accident
Investigation Board
Norway

Issued March 2010

REPORT SL 2010/05

REPORT ON SERIOUS AVIATION INCIDENT AT SANDEFJORD AIRPORT TORP 26 MARCH 2006 INVOLVING AIRBUS A321 OY-VKA OPERATED BY MY TRAVEL AIRWAYS SCANDINAVIA

This report has been translated into English and published by the AIBN to facilitate access by international readers. As accurate as the translation might be, the original Norwegian text takes precedence as the report of reference.

The Accident Investigation Board has compiled this report for the sole purpose of improving flight safety. The object of any investigation is to identify faults or discrepancies which may endanger flight safety, whether or not these are causal factors in the accident, and to make safety recommendations. It is not the Board's task to apportion blame or liability. Use of this report for any other purpose than for flight safety should be avoided.

Photos: AIBN and Trond Isaksen/OSL

CONTENTS

SERIOUS AVIATION INCIDENT REPORT

Aircraft:	Airbus A321-211
Nationality and registration:	Danish, OY-VKA
Owner:	Sunshine Leasing Ltd, Cayman Islands
User:	My Travel Airways Scandinavia[1], Denmark
Crew:	2 pilots and 5 cabin crew
Passengers:	210 adults and 6 children
Place of incident:	Sandefjord Airport Torp (ENTO), runway 18
Time and date of incident:	Sunday 26 March 2006 at 19:58 hrs.

All times and dates referred to in this report are stated in local time (UTC + 2 hours) unless otherwise specified.

INCIDENT NOTIFICATION

The Aviation Section on-call service (currently the aviation department) of the Accident Investigation Board of Norway (AIBN) was notified of the accident by the air traffic controller on duty at ENTO. An accident investigation inspector arrived on the scene the same night, while a second accident investigation inspector arrived at Torp the following morning.

SUMMARY

An Airbus A321, with registration OY-VKA and flight number VKG866, flew from Tenerife Airport (GCTS) to Sandefjord Airport Torp (ENTO) on 26th of March 2006.

The first officer was Pilot Flying (PF) and the commander was Pilot Not Flying (PNF). The crew reviewed updated weather and runway status before commencing the approach to ENTO. Air Traffic Information Services (ATIS) indicated dry runway and Braking Action (BA) GOOD.

When checking in on TWR frequency, the crew was informed that the runway was contaminated by 8 mm wet snow with a measured (Friction Coefficient, FC) of 32-33-31. These numbers indicated a MEDIUM BA.

The crew requested wind information in order to check for any crosswind or tailwind limitations. They made a mental consideration regarding the landing conditions and decided that it was acceptable to perform the landing. The airplane got high on the glide slope after passing 250 ft Radio Height. This resulted in a touch down approximately 780 metres from the threshold. After landing the crew experienced POOR braking action and suspected auto brake failure. The first officer performed maximum manual braking without noticing any BA. After landing the crew

[1] MyTravel Airways Scandinavia AS changed its name to Thomas Cook Airlines Scandinavia AS effective from 9 May 2008

experienced POOR BA and suspected a brake failure. The commander took control, pulled the Park Brake (PB) and steered the aircraft with Nose Wheel Steering (NWS) towards the left side of the runway with guidance from the first officer.

The effect of the PB and NWS was that the aircraft skidded sideways towards the end of the runway 18. This resulted in increased deceleration and the aircraft stopped at the very end of the hard surfaced runway, with the nose wheel against a concrete antennae base.

The crew advised the TWR about the anticipated runway excursion while the aircraft skidded towards the end. This allowed the TWR to alert the fire and rescue crew even before the aircraft had stopped. The fire and rescue service functioned as expected.

No persons were injured and the aircraft got some skin and nose wheel damage. The commander shut down the engines and evacuated the passengers through the forward left cabin door. The passengers were transported to the terminal building by buses while the crew remained in the aircraft being towed to the terminal.

This incident is similar to several other runway excursions on slippery runways in Norway during the later years. The incidents have many similar causal factors and AIBN does not see any safety benefits of investigating each of these individual incidents. AIBN is therefore working on a general report on winter operations and friction measurements. That report will highlight the common cause factors related in this type of incidents. The report will specifically highlight safety areas of general nature which are outside of the airline operators direct are of responsibility. This incident at Sandefjord Airport Torp is investigated separately in order to highlight the safety areas which MyTravel Scandinavia (now Thomas Cook Airlines Scandinavia) and Sandefjord Airport Torp have influence on. AIBN considers that these safety areas should be dealt with before the general report is issued.

Accident Investigation Board Norway (AIBN)'s investigations are in line with earlier investigation results regarding contaminated and slippery runways. AIBN is forwarding five safety recommendations.

1. FACTUAL INFORMATION

1.1 Course of events

1.1.1 Viking 866 (VKG866), an Airbus A321 OY-VKA took off from Tenerife airport (GCTS) at 1521 hrs for Sandefjord Airport Torp (ENTO). The first officer flew the plane, (Pilot Flying, PF) while the commander was Pilot Not Flying (PNF).

1.1.2 The weather forecast for Torp predicted snowfall after 1400 hrs with visibility 4 000 m in snow, temporary visibility down to 1 200 m and vertical visibility down to 800 ft in snow. Based on the received information the crew did not expect any problems related to the weather or runway conditions.

1.1.3 Around 1920 hrs snow began to gather on the runway. Due to the air traffic situation and an operating interruption on a sweeper, no sweeping was initiated. It was instead decided to conduct a new runway inspection.

1.1.4 OY-VKA's flight up to the planning of its approach to ENTO proceeded in the normal manner and according to the flight plan. The crew started planning the approach to ENTO when at around 180 NM south. Based on the weather forecast received earlier (TAF 12-21) prior to departure from GCTS, the crew expected an approach to runway 36. Runway 36 at ENTO does not have an an Instrument Landing System (ILS) and the instrument approaches to this runway are based on VHF Omnidirectional Ranging (VOR) and Non Directional Beacon (NDB) with higher minima (465 and 535 ft RH respectively).

1.1.5 Before their descent towards Torp, the crew gathered information from the Air Traffic Information Services (ATIS). This stated that runway 18 was in use, with 3 kt tailwind and a dry runway. Visibility was 2 500 m and the cloud base was 500 ft. Based on the updated information on weather and runway conditions, the crew assessed landing conditions to be good, and accepted runway 36. They did not foresee any problems.

1.1.6 The planned landing speed for the aircraft was based on a landing mass of 72 000 kg (72 metric tons), giving a V_{ref} (threshold speed) of 137 Knots Indicated Airspeed (KIAS). The V_{ref} was calculated automatically by the aircraft's Flight Management and Guidance Computer (FMGC) based on the aircraft's relevant landing mass. The crew used autothrust which is normal during approach. The FMGC automatically added 5 kt to the V_{ref} in order to attain a V_{app} (approach speed, VLS) of 142 KIAS. The additional 5 kt would compensate for the automatic thrust system (autothrust), which is normally kept on until the flare prior to landing.

1.1.7 The engine "anti-ice" function was engaged before passing 10 000 ft and the aircraft entered clouds just afterwards. Based on the icing indications, the V_{app} was increased by +5 kt to 147 KIAS. This gave a speed +5 kt higher than the FMGC adjusted landing speed (V_{app}) of 142 KIAS for the planned landing mass. The aircraft was configured for landing from an Instrument Landing System (ILS) when passing 2 000 ft in stabilised descent.

1.1.8 At 1945 hrs Airport Supervisor called the TWR and requested permission to inspect the runway. This was approved, and Airport Supervisor asked how long it was until the next movement. The air traffic controller replied that it was about 10 minutes to landing (VKG866). The Airport Supervisor said that he would start a braking test from the north.

1.1.9 At 1949 hrs, TWR informed the Airport Supervisor about an aircraft that was ready for take-off and asked if the braking-test vehicle could stop at the southern end when arriving there. The Airport Supervisor replied that he could, and that this would give him an indication of the runway conditions. He informed TWR that braking conditions had deteriorated to below GOOD (Norwegian "God", ref. Appendix H) which had been the case up till then. TWR asked if it was possible to complete the braking test after the flight departure. The Airport Supervisor replied that he would have to begin the braking test anew from the north, in order to comply with the requirements (a braking test must be performed in a continuous action for both runway directions).

1.1.10 At 1951 hrs, the Airport Supervisor called TWR and asked whether he was able to get back up to the northern end again before the next landing (VKG866). The air traffic controller replied that there was not enough time. The Airport Supervisor then stated that the runway had a 100 % wet snow contaminant of 8 mm depth, and that the friction figures were 32-33-31 measured at one side of the runway.

1.1.11 At 1952 hrs, the air traffic controller again asked whether the Airport Supervisor could reach the north end of the runway to start a new, complete brake test. The Airport Supervisor replied that they were planning to start sweeping after the announced

(VKG866). The air traffic controller replied that traffic was somewhat spread out. The Airport Supervisor then decided to begin a new complete brake testing from the north, and drove north on TWY Y.

1.1.12 At 1954 hrs (3 min.before landing) flight VKG866 checked in on TWR frequency and reported established on the Instrument Landing System (ILS), passing 7.5 NM. TWR informed them that the wind was 030° 3 kt and that the Braking Action was 32-33-31 (MEDIUM) with 8 millimetres of wet snow contamination. This was the first time the crew became aware that the runway was contaminated by snow. This, however, did not alarm them. With a MEDIUM Braking Action, there should be no problems coming to a halt on the runway available. The commander set the Autobrake on Medium when descending through 450 ft. This was indicated by the Blue ON light in the AB panel, which indicated that the AB system was armed. In order for the Green DECEL (deceleration) light to light up the AB system must have been active during 5 seconds in Medium setting provided 80 % of the required deceleration (Medium, 3 m/s^2) was reached.

1.1.13 At 1955 hrs, the commander asked for a wind check. This was reported to be 050° 5 kt. Right afterwards the VKG866 received clearance to land on runway 18. The Flight Data Recorder (FDR) data indicated that OY-VKA was stabilised on the Glide Slope (GS) until passing a Radio Height (RH) of approximately 250 ft. Thereafter an increasing positive deviation developed. This caused the commander to give a warning (*”call out”*) to the PF. The PF was unable to correct the increasing deviation from the glide slope and approached 50 ft RH more than one dot high on GS. The FDR data indicate that OY-VKA passed the threashold height about 10 ft high.

1.1.14 At 19:57:37 the OY-VKA touched down approx. 787 m from the threshold of runway 18 after a soft flare and touche down. This was 357 m further into the runway than usual. The aircraft landed at a speed of 140 KIAS. The FDR data show that the PF (first officer) put both engines into full reverse at the same time as the main wheels touched down (indicated by the operation of the main wheels "squat" switches) and before the nose wheel "squat" switch had operated. The commander looked at the AB panel. This should have indicated green (DECEL), indicating that 80 % of the selected medium decelration rate of 3 m/s^2 (0.31G) was achieved. The commander observed no lights in the panel which indicated "black". Not even the Blue ON (arm) light was on. The commander therefore pressed the switch to rearm the AB MED (Medium) system without any effect. The FDR data confirmed these actions. The first officer had observed that the commander had problems with the AB system, and depressed the brake pedals fully in order to brake manually.The Flight Data Recorder (FDR) print-out shows that the AB switch system worked normally but that the AB DEC MED arming function decoupled at the same instant the nose wheel touched down. FDR data confirmed that the AB MED systemet was reset without the wanted effect, and that the AB var selected ON during the whole braking run (cf. Appendix B). The FDR data showed that the manual braking started 8 seconds after touch down. At the same instant the AB DEC MED arming light went out the second time. The crew did not feel any braking action from the first officer's manual braking and the commander took control (PF) of the aircraft half-way down the runway. The FDR data show that the Airplane Braking Coefficient (ABC) with full manual braking was in the order of 0.05 (POOR, cf. Fig. 6). He tried turning the parking brake on and off (*cycle*), but did still not feel any Braking Action. When passing the position indicating there was only 800-1 000 m runway left, he therefore engaged the parking brake fully. By then, the crew had realised that they would not be able to stop the aircraft on the runway.

1.1.15 At 19:57:48 hrs the commander called up the TWR, informing them they would be going off the runway *("we are going off the runway"*). When receiving this message, the air traffic controller was talking to the Airport Supervisor, discussing the braking measurements. At the same time a phone call came in from Farris Approach. The air traffic controller therefore did not catch the message from VKG866 and asked them to repeat at 19:58:02 hrs. At 19:58:03 hrs, the commander responded that they had an emergency and that they would be going off the runway and would need rescue personnel *("we have an emergency, we are getting off the runway here, we need rescue*"). The first officer made an observation of the conditions around the end of the runway, and saw that the terrain seemed less undulating on the left-hand side of the runway. He therefore suggested to the commander to steer towards the left-hand side of the runway. The commander turned the nose wheel steering to the left, but he did not feel any difference in braking action after having engaged the parking brake. However, the aircraft started skidding with the nose turning to the left, and the crew could feel a better braking action (retardation). At 19:58:30 the aircraft came to a standstill at the very end of the tarmac strip with the engines still in full reverse, whereupon the commander set the engines to idle. The aircraft stopped as the nose wheel collided with a concrete base for the Localizer Monitor antenna which was located at the end of the runway strip. The aircraft remained standing with the nose facing southeast (HDG 114º), about 65° off the runway direction (179.33º).

1.1.16 The commander considered that the aircraft was in a horizontal position, and apparently undamaged. He therefore used the Public Address (PA) system to ask the cabin crew and passengers to remain seated. After that, he shut down engine no. 2 and engaged the Auxiliary Power Unit (APU), before shutting down engine no. 1. He then called for the Cabin Chief, and asked this person to go and check by the wings for any signs of damage or fire, as they could smell a slight whiff of burnt rubber.

1.1.17 At 19:58:13 hrs while the VKG 866 was still skidding on the runway, the air traffic controller raised the alarm and ordered fire emergency call-out to threshold south.

1.1.18 At 19:58:39 hrs, approx. 9 seconds after the aircraft came to a standstill, the commander called the TWR and informed them that they had gone off the runway and were in need of assistance. The air traffic controller replied that the fire crew was on their way. The commander then briefed the passengers on what had happened. The passengers and cabin crew kept calm and waited.

1.1.19 At 19:58:44 TWR called up fire engine no. 1 and repeated the order for a call-out to threshold south.

1.1.20 At 19:58:52 hrs, the commander called up the TWR and asked them to send out busses to carry the passengers to the terminal.

1.1.21 At 19:59:44 hrs, fire engine no. 1 issued a warning on the radio that the fire engines had to drive carefully because the surface was very slippery. At 20:00:02 hrs, fire engine no. 1 called in to say that it was in position at the aircraft. At 20:00:10 hrs, fire engine no. 3 reported being in position and at 20:00:20 hrs so did fire engine no. 2 and 4.

1.1.22 At 20:00:30 hrs, the commander again called the TWR and requested that buses be sent out. At 20:08:35 TWR reported that a staircase and some other vehicles were on their way.

1.1.23 At 20:49:23 hrs, TWR reported that busses were on their way. These had been delayed because of snowfall, slippery roads and an accident on the slippery main road E18. The passengers were transported into the terminal approx. one hour after landing.

1.1.24 The aircraft was eventually towed in to the terminal and the runway was reopened. The first landing after the incident took place at 2357 hrs.

1.2 Personal injuries

Table 1: Personal injuries

Injuries	Crew	Passengers	Others
Deceased			
Serious			
Light/none	7	210+6	0

1.3 Damage to the aircraft

The aircraft sustained minor damage on the nose wheel and fuselage on the right-hand-side. Ref. item 1.12.

1.4 Other damage

The Localizer Monitoring antenna and the base at the end of runway 18 were damaged.

Figure 1: Damaged Localizer Monitoring antenna with concrete base.

Figure 2: Repaired Localizer Monitoring antenna.

1.5 Personnel information

1.5.1 Commander

Table 2: Flight hours - commander

Flight hours	All types	Present type
Past 24 hours	10	10
Past 3 days	12	12
Past 30 days	62	62
Past 90 days	172	172
Total	11 500	4 500

The commander was male, 45 years old, and held a JAR FCL ATPL (A) valid until 31 March 2007. He was qualified for Airbus A318/319/320/321. His latest Operational Proficiency Check (OPC) took place on 8 February 2006, valid until 31 March 2007. The commander held a medical certificate class 1 without restrictions, valid until 11 April 2006.

The commander had slept 8 hours before the working day began, and has stated to the AIBN that he felt rested before the flight.

1.5.2 First officer

Table 3: Flight hours – first officer

Flight hours	All types	Present type
Past 24 hours	5	5
Past 3 days	12	12
Past 30 days	143	143
Past 90 days	271	271
Total	3 984	1 715

The first officer was male, 43 years of age, and held a JAR FCL CPL (A) valid until 10 December 2007 and an IR(A)ME valid until 31 March 2007. He was qualified for Airbus A319/320/321. The first officer's latest OPC was dated 8 February 2006, valid until 31 March 2007. The first officer had a medical certificate class 1 without restrictions, valid until 5 October 2006.

The first officer had slept 9 hours and felt rested before the flight.

1.5.3 Cabin Crew

There was a cabin crew of five onboard, one of which was the Cabin Chief.

1.6 The aircraft

1.6.1 In general

The Airbus A321 is a two-engine, low-wing aircraft with turbofan engines and medium reach. The aircraft is developed and produced by Airbus Industrie. The cabin holds 211 passenger seats.

1.6.2 Aircraft specs.

Manufacturer:	Airbus Industrie
Model:	Airbus A321-211
Certificate of airworthiness:	Valid until 2 April 2007
Year of production:	2003
Serial number:	1881
Total flying time, hours:	12.363
Total no. of cycles:	Not stated
Engine type:	CFM 56-5B3P
Engine time since last maintenance:	No 1 121 hours No 2 121 hours

1.6.3 Maintenance

The aircraft was registered in Denmark and maintained in accordance with JAR 145. The aircraft had flown 121 hours since its latest "A" check. The Accident Investigation Board has found nothing to indicate that the aircraft was not airworthy or had any limitations prior to the incident.

1.6.4 Mass and balance

The aircraft had a takeoff mass of 86.392 kg, with the centre of gravity in position 22.8%. Maximum takeoff mass was 89.000 kg, with a CG limit between 19.5 and 36% Mean Aerodynamic Chord (MAC). On landing, the aircraft had a mass of 71.800 kg and a centre of gravity 25% MAC with CG limits of 15-35% MAC. Maximum certified landing mass on dry runway was 77.000 kg (certified data). Maximum operational landing mass on contaminated runway 18 ENTO with 6 mm slush and 10 kt tailwind was 88.637 kg (advisory data). Maximum operational landing mass on slippery runway 18 ENTO with reported FC 0.25 and 5 kt tailwind was 79.024 kg. Mass and balance were inside current limits at takeoff and landing.

1.6.5 Fuel

The aircraft took off with 18.000 kg JET A-1 fuel and carried 3.400 kg fuel on board at the time of the incident.

1.7 The weather

1.7.1 In general

The weather conditions had been good for most of the day, with no precipitation, dry, black runway and not much wind. An incoming weather front was forecast, bringing snow from 1400 hrs onwards. An inspection of the runway was performed at 1650 hrs. Conditions at the time showed a light snowfall, -1 °C, snow-free and wet runway. The temperature fell slightly after 1700 hrs, down to -2 °C. The runway was still not covered by snow. Only after 1900 hrs did the snow begin to cover the runway.

1.7.2 TAF

ENTO 261100Z 261221 05010KT 9999 SCT020 BKN040 BECMG 1214 4000 –SN BKN012 TEMPO 1321 1200 SN VV008=

ENTO 261400Z 261522 08010KT 8000 –SN SCT020 BKN030 TEMPO 1522 1200 SN VV008=

1.7.3 METAR

ENTO 261520Z 10004KT 020V140 3700 –SN SCT008 BKN025 M02/M03 Q1008=

ENTO 261550Z 08006KT 1600 –SN SCT006 BKN025 M02/M03 Q1008=

ENTO 261620Z 05005KT 360V080 2000 –SN SCT005 BKN025 M02/M03 Q1008=

ENTO 251650Z 04005KT 1700 –SN SCT005 BKN025 M02/M03 Q1007=

ENTO 261720Z 03006KT 2500 -SN BKN005 M02/M03 Q1008=

ENTO 261750Z 04006KT 1500 -SN BKN005 M02/M03 Q1007=

1.7.4 ATIS

ATIS 1720 C: *This is Torp information C time 1720. Runway in use 18. Braking action good. Runway dry. Transition level 85. Wind 030 degrees 06 knots. Visibility 2 500 metres. Weather light snow. Clouds broken 500 feet. Temperature minus 02 dewpoint minus 03 QNH 1008. This was Torp information C.*

ATIS 1750 D: *This is Torp information D. Time 1750. Runway in use 18. Braking action good. Runway dry. Transition level 85. Wind 040 degrees 06 knots. Visibility 1 500* *metres. Weather snow. Clouds broken 500 feet. Temperature minus 02 dewpoint minus 03. QNH 1007. This was Torp information D.*

1.7.5 Weather information received by the aircraft crew

1.7.5.1 The crew had received the company's weather and NOTAM briefing package shortly after arriving at Tenerife airport (GCTS). No SNOWTAM was received, as the first SNOWTAM for ENTO was only issued at 1450 hrs UTC. This was around one hour and thirty minutes after takeoff from GCTS. This SNOWTAM did not contain any information on snow contamination of the runway, but merely said that the runway was wet with good braking action.

1.7.5.2 The briefing package included TAF 1221 UTC which forecast snowfall to begin at around 1214 UTC and continuing, with temporary visibility in snow showers of 1 200 m and vertical visibility of 800 ft for the whole period.

1.7.5.3 Before starting their descent, the crew checked the ENTO ATIS 1720 UTC. This indicated approx. 3 kt tailwinds, light snowfall, but dry runway and good Braking Action. The crew consulted their Performance Manual with specific pages for ENTO (Appendix E-1/2). The crew ascertained that even with some tailwind they could accept landing on snow with a landing mass of up to 100 metric tons.

1.7.6 SNOWTAM

1.7.6.1 SNOWTAM issued at 1450 hrs UTC showed that the runway was moist, with an estimated good Braking Action (GOOD, 5. See Appendix H).

1.7.6.2 SNOWTAM issued at 2115 hrs UTC (following the incident and fresh treatment of the runway) showed that the runway was covered 100% with 3 millimetre dry snow on sanded ice. Friction was measured with BV-11 to be 41-39-39.

1.7.7 Runway reports

1.7.7.1 Runway report from 1451 hrs UTC showed the runway to be damp in light snowfall. Air temperature - 1°C. Braking Action was estimated to be GOOD.

1.7.7.2 Runway report from 1741 hrs UTC showed that the runway was 100% covered with 8 millimetres of wet snow. No sand had been spread on the runway. Friction was measured with BV-11 on runway 18 to 32-33-31. This was an incomplete friction measurement in the sense that only one half of the runway was measured (only measured in the southern direction on one side of the centre line on runway 18). The air temperature was not recorded. The reason for the incomplete friction measurements was that the airport vehicle had to interrupt its friction measuring due to ongoing air traffic. WIF426 was about to take off and VKG866 (OY-VKA) had reported in for landing.

1.7.7.3 The runway report from 2028 hrs UTC (2.5 hr after the incident) showed that the runway was contaminated with 13 millimetres of dry, loose snow. Friction was measured with BV-11 to 29-30-29. Air temperature was not recorded.

1.7.7.4 The runway report from 2052 UTC showed that the runway had been ploughed, swept and sanded. Runway 18 contaminated by 3 millimetres dry snow on ice. Measured friction (BV-11) was 41-39-39.

1.7.8 Runway treatment

1.7.8.1 The Airport Supervisor had planned to sweep the runway. This was postponed due to technical problems with a sweeper and frequent departures and landings. The Airport Supervisor checked with TWR regarding the air traffic and was informed that the traffic situation did not much allow for immediate sweeping. It was decided to carry out a friction measurement instead. It was estimated that they had 10 minutes available to perform friction measurement.

1.7.8.2 About 3 minutes later, while the Airport Supervisor was driving southwards along runway 18 while performing the friction measurement, a message came from TWR concerning a takeoff by WIF426. Consequently the Airport Supervisor had to break off the friction measurement, having completed friction testing on one side of the runway only. The Airport Supervisor therefore had to drive to the northern end and restart friction measurements from the north. While the Airport Supervisor was driving north on TWY Y, the VKG866 landed.

1.7.8.3 The runway was closed for about three hours after the landing while the aircraft was evacuated and towed to the terminal, and the runway was ploughed, swept and sanded.

Figure 3: Reflections in frozen moisture in the vehicle tracks indicate a slippery runway.

1.7.9 Friction measurement

The runway friction measurements at ENTO were performed with a Skiddometer (SKH/BV-11) with high pressure tyres. The measurements were to be performed 3-7 metres from the centre line on both sides of the runway, from north to south and vice versa. The measurement speed was set at 65 kt.

1.8 Navigational aids

ENTO was equipped with NDB (Dalen 404 KHz DA and Sandefjord 283 SF), VOR DME (113.850 MHz TOR) and ILS/DME (108.300 MHz TP).

All navigational aids were operative at the time of the incident.

Runway 36 was not equipped with Instrument Landing System (ILS), but had Non Directional Beacon (NDB) and VHF Omnidirectional Ranging (VOR) approach aids.

Runway 18 was equipped with ILS and had the lowest minima of 200 ft Radio Height (RH), while the minimas to runway 36 were 465 ft RH (VOR) and 535 ft RH (NDB) respectively.

1.9 Communication network

ENTO was equipped with APP (Farris) 134.050 MHz, TWR 118.650 MHz and airport frequency for vehicles and fire engines 121.8 MHz.

The communication network worked as normal at the time of the incident.

1.10 Airport and aids

AIP NORGE/NORWAY **AD 2 ENTO 2 - 1**

AERODROME CHART	59°11'12"N 010°15'31"E WGS 84	AD ELEV 286 FT	ATIS 119.075 MHz TWR 118.650 MHz	SANDEFJORD TORP NORWAY

RWY	BRG (GEO)	THRESHOLD		BEARING STRENGTH	DECLARED DISTANCES				TWY AND APRON
					TORA	ASDA	TODA	LDA	
18	179,33°	591151.70N	0101530,13 E	PCN – 45 F/B/X/U	2839	2839	2989	2569	APRON TERM S 200x80M, PCN-45/F/B/X/U
36	359,33°	591032,55N	0101531,94 E	PCN – 45 F/B/X/U	2789	2789	2939	2569	APRON CIV N 250x50M, PCN-30/F/B/X/U
									ASPH AND/OR CONC

Figure 4: Segment of the ENTO airport map.

1.10.1 Sandefjord Airport Torp (ENTO) had a 2 939 x 45 m tarmac runway entitled RWY 18/36. The total STRIP (hard surface) was 2 985 m. The area to the south of the threshold (THR) 36 was a concrete surface of 270 m length. RWY STRIP and Runway Emergency and Safety Area (RESA) came to an end at the end of the concrete surface.

1.10.2 RWY 18 had a Landing Distance Available (LDA) of 2 569 m and had a clearway (CWY) of 150 x 150 m at the end of the STRIP. Runway 18 had a positive slope (uphill) of 0.3 % the first 491 m from threashold 18, and negative slope (downhill) of -0.5% on the remaining part of the runway.

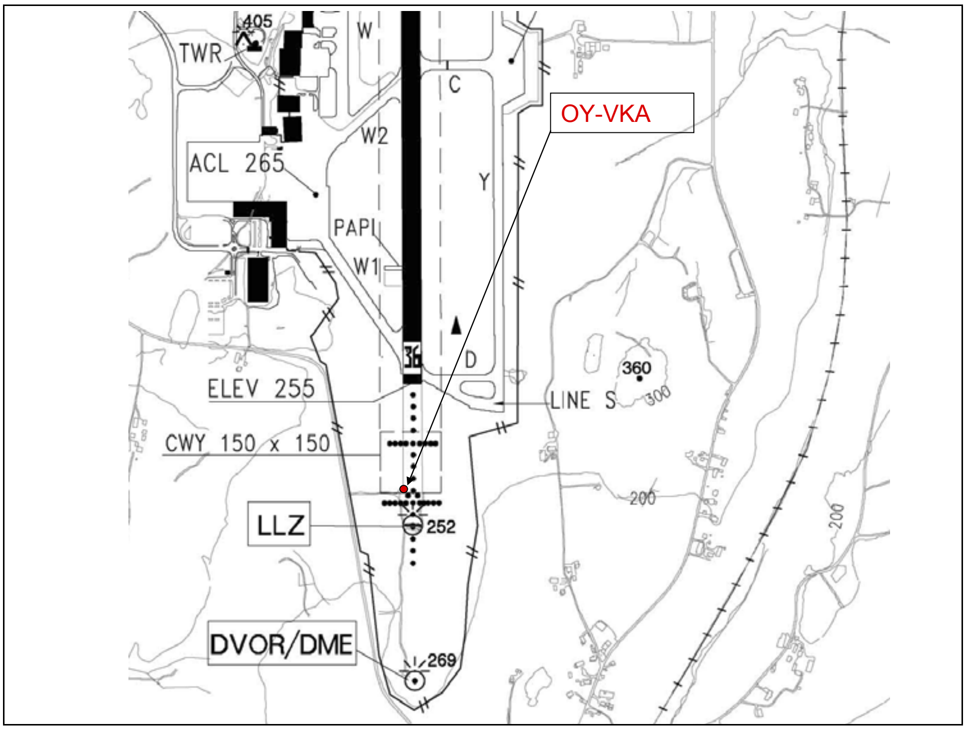


Figure 5: Stop position for OY-VKA.

1.11 Flight recorders

1.11.1 In general

1.11.2 Flight Data Recorder

1.11.2.1 The aircraft was equipped with a Flight Data Recorder (FDR) type Honeywell P/N FDR 980-4700-042, S/N SSFDR-08633, DMF 012002.

1.11.2.2 In addition, the aircraft was equipped with a Flight Data Information Measuring Unit (FDIMU), the same as a so-called Quick Access Recorder (QAR). This was used by the company's quality department for Operational Flight Data Monitoring.

1.11.3 Cockpit Voice Recorder

The aircraft was equipped with a Solid State Cockpit Voice Recorder (CVR), type Honeywell P/N CVR 980-6022-001, S/N CVR 120-06429, DMF 112003.

1.11.4 Playback

1.11.4.1 FDR and CVR were played at the Aircraft Accident Investigation Branch (AAIB) in the UK. The quality of the FDR and CVR data was good. See Appendix B.

1.11.4.2 AIBN had the FDR data analysed by Airbus in Toulouse. See Figures 6 and Figure 7. In addition, AIBN had the FDR data animated, using the Flightscape software at SAAB Aircraft in Sweden.

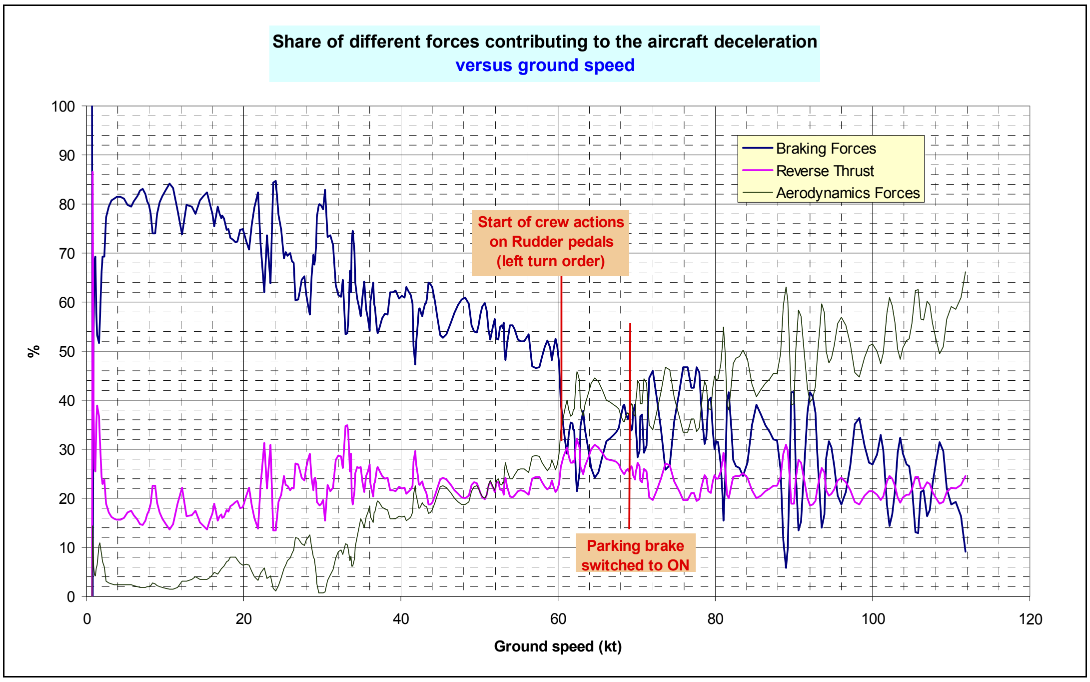


Figure 6: Graph showing the percentage distribution of braking forces from laps/spoiler, reversing and from wheel brakes.

The graph in Figure 6 shows that reversing contributed to approx. 20 % of the overall braking force and was relatively constant during most of the braking action. The graph further shows that the braking force from the wheel brakes contributed to approx. 20 % down to 60 kt. At this speed, the commander applied the parking brake and steered towards the left following advice from the first officer. The intention was to steer the aircraft towards the left side of the runway as the terrain on the left side looked better for a runway excursion. This caused the aircraft to unintentionally skid sideways while the mass velocity vector continued along the same path as before. This caused the main wheels and the nose wheels to skid sideways through the snow resulting in the retardation force from the runway surface contamination to increase to approx. 80 % of the total braking force towards the end of the braking run. The reversing continued to contribute the remaining 20 % of the total braking force down to about 20 kt.

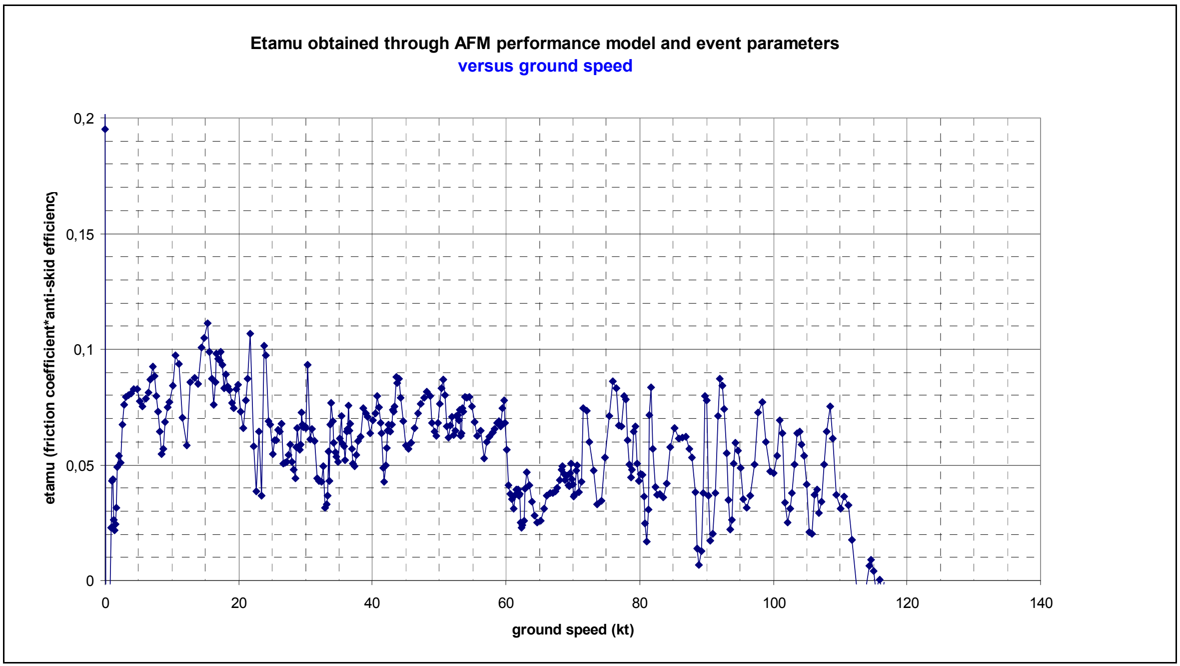


Figure 7: Graph showing the aircraft's effective brake coefficient.

The graph in Figure 7 shows that the aircraft's effective friction coefficient (*"airplane effective μ"* in the Airbus terminology, or Airplane Braking Coefficient (ABC in the Boeing terminology) was in the region of 0.05. This corresponds to POOR Braking Action.

1.11.4.3 FDR data showed that the aircraft began to come in high in relation to the glide slope from a radio height, (RH) of 250 ft. FDR data show that OY-VKA passed the runway threashold (normal height 50 ft RH) about 10 ft high (about 60 ft RH). Based on standard landing parameters, the aircraft touched down 787 m from the "runway threshold" (approx. 357 m further in than normal). The indicated landing speed was 140 KIAS with a 3 kt tailwind. The aircraft floated before landing softly on the runway.

1.12 The aircraft and scene of the incident

1.12.1 <u>The aircraft</u>

1.12.1.1 The aircraft sustained damage to the right-hand nosewheel rim and fuselage. The right-hand nosewheel rim was cracked by the concrete base and a bit of about 5 cm long was broken off from the rim. The right-hand nosewheel tyre was scraped on the side. Figure 8.

1.12.1.2 The lower fuselage sustained a small dent in the skin on the right-hand side. The damage came from the impact with the Localizer Monitoring antenna, when this was bent to the side by the fuselage. The indentation was localised between station nos. 14 and 15 and was around 10 x 14 millimetres long and approx. 1.8 millimetres deep. Figure 9.

Figure 8: Damage to the nosewheel rim.

Figure 9: Minor indentation in the fuselage between stations 14 and 15.

1.12.2 Scene of the incident

The aircraft stopped with the nosewheel perched against the concrete base of a Localizer Monitoring antenna and ended up standing across runway 18 with its nose facing approx. 65° (HDG 114º) off the runway direction, and with the right-hand side main wheel approx. 2 metres away from the end of the hard runway surface. Figures 10 and 11.

Figure 10: The aircraft stopped across runway 18 at the end of the hard surface.

Figure 11: The right main wheel ended up approx. 2 m from the end of the runway.

1.13 Medical matters

Not relevant.

1.14 Fire

There was no fire.

1.15 Survival aspects

1.15.1 Fire and rescue

1.15.1.1 The crew notified the TWR that they would be coming off the runway 42 seconds before the aircraft stopped. The air traffic controller did not grasp the first distress call. 15 seconds later the crew repeated the the call and informed the TWR about the impending runway excursion. 10 seconds later the controller alerted the emergency vehicles about the emergency situation (17 seconds before the aircraft came to a stop). Consequently, the fire and rescue vessels were on their way towards the aircraft by the time it came to a halt at the southern end of the runway. The first emergency vehicle reached the aircraft 109 seconds after the alarm was raised. The last vehicle was in position by the aircraft 127 seconds after the rescue alarm.

1.15.1.2 Norwegian regulations BSL E 4-4 specify that the emergency response time under normal visibility and driving conditions should be within 90 seconds, and under any condition to be limited to 120 seconds.

1.15.2 Evacuation

There was no material damage to the aircraft that had any impact on the crew or the passengers. No crew members or passengers were injured as a result of the incident. The commander could smell burnt rubber, but in his assessment the situation did not warrant immediate evacuation. He started up the Auxiliary Power Unit (APU) and shut down the engines, thereby keeping up the power supply and air conditioning facility in the cabin. He asked the crew and passengers to keep calm, and informed them that the aircraft would be evacuated in the normal manner. The airport provided an aircraft staircase, and the passengers were evacuated through the front cabin door and bussed to the airport terminal.

1.16 Special investigations

AIBN has not performed any special investigations requiring special attention. AIBN points to the investigations performed by Flight Safety Foundation (FSF), related to runway excursions. Cf. the FSF links:

http://www.flightsafety.org/current-safety-initiatives/runway-safety-initiative-rsi/runway-excursion-risk-reduction-rerr-toolkit

http://www.flightsafety.org/files/RERR/fsf-runway-excursions-report.pdf

1.17 Organisation and management

1.17.1 MyTravel Airways Scandinavia

1.17.1.1 MyTravel Airways Scandinavia (now Thomas Cook Airlines Scandinavia) is a charter company with operations out of Scandinavia. The company came about as a merger between Conair and Scanair (SAS' charter company) in 1994. Prior to the merger, both companies had 30 years' experience of flight operations. The company's main base is located at Copenhagen Airport Kastrup (EKCH), with operational bases at Stockholm Arlanda, Oslo Gardermoen and Helsinki Finland.

1.17.1.2 At the time of the incident the company was conducting international charter passenger flights. The company operated a fleet of 10 Airbus 320/321/330. At that time the number of employees was 840 people, consisting of 160 pilots, 600 cabin crew and approx. 120 maintenance personnel and administration staff.

1.17.1.3 MyTravel Airways Scandinavia's management and senior administrative personnel were headquartered at Copenhagen Airport Kastrup (EKCH), Dragør, Denmark. The company's Managing Director was the Accountable Manager. Director of Operations, Flight Operations Manager, Maintenance Manager, In-flight Services Director, Finance Director, Commercial Manager, Director of Human Resources, Head of Safety and Quality Managers for Operations and Maintenance, reported directly to the Accountable Manager.

1.17.2 Flight Operations Division

1.17.2.1 The Flight Operations Division had two areas of responsibility:

1. The Operations Director was responsible for the Operations Administration (financial responsibility)
2. The Flight Operations Manager was responsible for the Operational Safety (operative and flight safety responsibility).

1.17.2.2 The Flight Operations Manager was the supervisor for two Type Chief Pilots (TCPs) and two Chief Flight Instructors (CFIs) on the A320/21 and A330 respectively. In addition to the Operations Director and Flight Operations Manager, the Flight Operations Management Team consisted of:

a. Training Manager JAR-OPS 1, who was a Nominated Post Holder (NPH) and was responsible for all periodic flight training (OPC) and transfer training. He reported to the Flight Operations Manager on safety-related issues.

b. Head of Training JAR-FCL is an NPH (FCL), who was in charge of all type-related flight training. He reported to the Flight Operations Manager on safety-related issues.

c. Ground Operations manager was an NPH, and was in charge of the Operations Control Centre, Crew Planning and Ground Services departments. He reported to the Flight Operations Manager on safety-related issues.

1.17.2.3 The base captains located in Stockholm, Oslo and Helsinki reported directly to their respective Chief Pilots.

1.17.2.4 Issues related to flight safety are handled by the Safety Manager and Quality Manager Operations in their respective areas. They reported directly to the Accountable Manager.

1.17.2.5 MyTravel Airways Scandinavia had developed and implemented a Safety Management System (SMS) in line with ICAO doc 9859-AN/460 and CAP 712, approved by the Danish Civil Aviation Administration (LFV). This system comprised:

- Environment
- Quality
- Flight safety
- Cabin safety
- Ground safety
- Security
- Management response (contingency procedures).

The system was based on Teledyne AirFASE for Flight Data Monitoring, and Sentinel for mandatory flight safety reports. Audit Scheduling programming was performed using Microsoft Project and other in-house systems, including time control.

1.17.3 The company's procedures

1.17.3.1 *Flying in icing conditions.*

The Airbus FCOM 3.04.30 page 1, described the company's procedure for flying in icing conditions. In addition to having the Engine anti-ice and Wing anti-ice systems on, the following applied:

CAUTION

Extended flight, in icing conditions with the slats extended, should be avoided.

If there is evidence of significant ice accretion and to take into account ice formation on non heated structure, the minimum speed should be:

In configuration full, VLS + 5 knots, and the landing distance must be multiplied by 1.1.

In configuration lower than FULL, VLS + 10 knots, and the landing distance in CONF 3 must be multiplied by 1.15.

1.17.3.2 *Landing on contaminated runways.*

Airbus FCOM 2, paragraph 04.10 page 13 and PM 2.6. page 2, recommended the following procedure for landing on contaminated runways:

"FOLLOWING LANDING PROCEDURES CONSIDER

- *Avoid landing on contaminated runways if the antiskid is not functioning. The use of autobrake LOW or MED is recommended provided that the contamination is evenly distributed.*
- *Approach at the normal speed.*
- *Make a positive touchdown after a brief flare.*
- *As soon as the aircraft has touched down, lower the nose wheel onto the runway and select maximum reverse thrust.*
- *Do not hold the nose wheel off the ground.*
- *If necessary, the maximum reverse thrust can be used until the aircraft is fully stopped.*
- *If the runway length is limiting, apply the brakes before lowering the nose gear onto the runway, but be prepared to apply back stick to counter the nose down pitch produced by the brakes application. (The strength of this pitching moment will depend on the brake torque attainable on the slippery runway).*
- *Maintain directional control with the rudder as long as possible, use nose wheel steering with care.*

- *When the aircraft is at taxi speed, follow the recommendations for taxiing."*

1.17.3.3 *Loss of braking.*

Airbus FCOM 3.02.32 describes the procedure for brake failure:

"LOSS OF BRAKING
IF AUTOBRAKE SELECTED:

- BRAKE PEDALS…………………………………………………….PRESS

This will override the autobrake.

IF NO BRAKING AVAILABLE:

-REV……………………………………………………………………MAX

-BRAKE PEDALS…………………………………………………RELEASE

Brake pedals should be released when the A/SKID & N/W STRG selector is switched OFF, since the pedal force or displacement produces more braking action in alternate mode than in normal mode.

-A/SKID & N/W STRG…………………………………………………..OFF

Braking system reverts to alternate mode.

-BRAKE PEDALS……………………………………………………….PRESS

Apply brake with care, since initial pedal force or displacement produces more braking action in alternate mode than in normal mode.

-MAX BRK PR……………………………………………………1000 PSI

Monitor brake pressure or BRAKES PRESS indicator. Limit brake pressure to approximately 1000 psi and, at low ground speed, adjust brake pressure as required.

If STILL NO BRAKING

- PARKING BRAKE…………………………………………………..USE

Use short successive parking brake applications to stop the aircraft. Brake onset asymmetry may be felt at each parking brake application. If possible, delay the use of the parking brake until low speed, to reduce the risk of tire burst and lateral control difficulties."

1.18 Other information

1.18.1 Earlier incidents

This incident is one in a series of similar incidents with runway excursions from slippery runways in Norway over the past 10 years. The incidents have many of the same causal factors, and AIBN is therefore working on a general report on the subject of winter operations and friction measurements. This general report aims to highlight the common causal factors of these incidents and aims in particular to shed light on safety areas of a general nature which lie outside the various airline and airport operators' direct areas of responsibility. The incident on Sandefjord Airport Torp has been especially highlighted in order to clarify safety areas for which MyTravel Scandinavia (now Thomas Cook

Airlines Scandinavia) and Sandefjord Airport Torp has a possibility to influence. It is the opinion of AIBN that these should be highlighted before the general report is published.

1.18.1.1 In connection with the ongoing general report, AIBN proposed four immediate safety recommendations on 7 September 2006. These are still being processed by the Civil Aviation Authority of Norway:

”Immediate safety recommendation SL 06/1350-1

AIP Norge and BSL E lay down the Norwegian regulations on friction measuring devices and measurement areas. AIBN has shown that the relevant friction figures often deviate from the measured/reported figures. Experience shows that none of the approved friction measurement devices/appliances is reliable in moist/wet conditions, including under temperature conditions with a difference of 3°C or less between the air temperature and dewpoint temperature. AIBN therefore holds that the reported friction in moist/wet conditions should be reported as DÅRLIG/POOR. The Accident Investigation Board recommends that the Civil Aviation Authority should consider changing the measurement areas for the approved friction measurement devices in AIP Norway and BSL E.

Immediate safety recommendation SL 06/1350-2

The Accident Investigation Board’s investigations show that the various airlines use different correlation curves/tables. The investigations show that several of these correlation curves are based on uncertain foundations, and that they provide highly inaccurate/unreliable braking values for the relevant aircraft types. The ICAO SNOWTAM table for measured friction figures is based on measured figures in hundreths, and does not depend on the type of friction measuring device used. The Accident Investigation Board’s investigations show that the different friction measuring devices give different measurements on the same surface. AIP Norway describes the use of friction measuring equipment in general and warns that there are such large uncertainties in the measurements that the accuracy of reporting should not be higher than tenths. Given these circumstances, AIBN recommends that the Civil Aviation Authority considers simplifying the SNOWTAM table by eliminating the intermediate levels so that one is left with the areas Good, Medium and Poor, as well as removing hundredths and excluding the use of interpolation between the areas.

Immediate safety recommendation SL 06/1350-3 *(this safety recommendation is not related to the incident with WIF9862, but to winter operations in general).*

The Accident Investigation Board’s investigations show that performance data for landing on slippery runways using engine thrust (reversing) has been published for newer aircraft types (e.g. Airbus and newer Boeing aircraft). Such data have not been published for older aircraft types. The investigations further show that the effect of reversing engines is limited to approximately 25% of all available braking force and that this braking force should constitute a backup when landing on slippery runways. AIBN recommends that the Civil Aviation Authority should consider not allowing the inclusion of thrust reversal in the calculated actual (the last 30 min before landing) stopping distance on slippery runways.

Immediate safety recommendation SL 06/1350-4

The AIBN investigations show that the airlines’ crosswind limitations in combination with slippery runways are far too optimistic. The investigations have also confirmed that for certain aircraft types, these tables do not derive from the manufacturer of the *aircraft, but have been prepared by individual airlines based on experience. None of the side wind tables have been approved by the authorities. Transport Canada has published one such table of crosswind versus friction numbers. This is far more conservative than the tables used by Norwegian airlines. The AIBN recommends that the Civil Aviation Authority assesses the airlines' crosswind limitations in relation to friction coefficients/braking action, and also considers whether these should be approved by the authorities.*

1.18.1.2 No Norwegian regulations have been amended thus far, but the Civil Aviation Authority has initiated an internal revision of the text of AIP Norway and BSL E.

1.18.1.3 The specific incident at Torp which is the subject of this report, illustrates the problems of trusting measured friction figures in all types of conditions. Friction figures were measured to fall inside the area 31-33, which is classified as MEDIUM (medium Braking Action). Even so, the real friction came under the category of POOR (poor Braking Action). Due to the low braking action the crew suspected brake failure.

1.18.1.4 AIBN refers to investigation reports following a serious aviation incident at Harstad/Narvik airport Evenes with B737-500 LN-BRV (Reference 1), an aviation incident at Kirkenes airport Høybuktmoen with DHC-8-103 LN-WIR (Reference 2), both on 30 January 2005. In addition, there was a serious aviation incident at Harstad/Narvik airport Evenes with Airbus A320 G-CRPH, on 25 November 2004 (Reference 3).

1.18.1.5 AIBN would also refer to the following incidents related to slippery runways that have been reported over the past 5 years:

- A320 G-CRPH at Harstad/Narvik airport Evenes 25 November 2004
- A320 (Flight JKK1392) at Harstad/Narvik airport Evenes 18 January 2005
- B737 LN-BRV at Harstad/Narvik airport Evenes 30 January 2005
- DHC-8 LN-WIR at Kirkenes airport Høybuktmoen 30 January 2005
- B737 LN-BUF at Svalbard airport Longyearbyen 16 January 2006
- DHC-8 LN-WIA at Kirkenes airport Høybuktmoen 22 January 2006
- A321 OY-VKA at Sandefjord Airport Torp 26 March 2006 (this incident)
- B737 PH-BPC at Stavanger airport Sola 21 January 2007
- B737 LN-TUL at Bardufoss airport 2 February 2007
- B737 LN-BRO at Tromsø airport Langnes 19 December 2007
- A321 OY-VKC at Oslo airport Gardermoen 5 January 2008
- B737 PH-BXU at Oslo airport Gardermoen 1 February 2008
- B737 LN-KKS at Bardufoss airport 13. Januar 2010
- Bombardier 600-CL SE-DUY at Svalbard airport Longyear 25. Januar 2010

Of the above incidents, the G-CRPH, LN-BRV, LN-WIR, OY-VKA has been, and SE-DUY will be, subjected to individual investigations, while the remaining incidents are included in the general report.

1.18.2 Friction measurements and uncertainty

1.18.2.1 The Accident Investigation Board has been able to document that friction measurements made with all the approved types of friction measuring devices are associated with uncertainties of ± 0.10 in dry conditions, and of ± 0.20 in wet (moist) conditions. This is shown in Table 1 of Appendix G.

1.18.2.2 AIBN investigations also show that there are moist conditions with a dew point spread (the difference between air temperature and dew point) of < 3 K, espesially when the temperature is below freezing. This may lead to a considerable discrepancy between the measured friction and the actual friction experienced. At the time of the incident in question, the dew point spread equalled 1 K.

1.18.2.3 The Accident Investigation Board also refers to the Joint Winter Runway Friction Measurement Program (JWRFMP) which was carried out in Canada in the time period 1995-2004. Figure 1 of Appendix G comes from Transport Canada and demonstrates some of the uncertainties with regard to friction measurements on contaminated runway surfaces.

1.18.3 Norwegian regulations relating to winter maintenance of runways

1.18.3.1 Aeronautical Information Publication Norway (AIP Norway[2]), AD 1.2, items 2.4 and 2.5 describe the Norwegian runway treatment and reporting requirements. This is shown in Appendix H.

1.18.3.2 Norwegian definitions of the different types of contamination are documented in BSL E and are based on the corresponding definitions in JAR-OPS 1. See Appendix H.

1.18.3.3 At the time of the incident there was a valid Aeronautical Information Circular (AIC) issued by the Civil Aviation Authority (LT), which adjusted the reporting intervals to 3 mm for slush, 6 mm for wet snow and 8 mm for dry snow. This meant that e.g. 4 mm of slush should be reported as 6 mm, 9 mm wet snow as 12 mm, and 10 mm of dry snow should be reported as 16 mm. This was a deviation from the ICAO recommended figures of 3 mm slush, 10 mm wet snow and 20 mm dry snow.

1.18.3.4 Prior to the landing of OY-VKA, reports stated 8 mm of wet snow. Based on the applicable AIC this should have been reported as 12 mm of wet snow. If the snow had been classified as dry, however, it should have been reported in as 8 mm.

1.18.3.5 AIP Norway, AD 1.2, item 2.6.3 provide definitions of the accepted measuring areas for the approved friction measurement devices. Skiddometer with high-pressure tyres (SKH) and Surface Friction Tester with high-pressure tyres (SFH) were approved for runways contaminated with up to 25 mm dry snow and up to 3 mm wet snow or slush. Excerpts from AIP Norway, AD 1.2 are shown in Appendix H.

[2] Aeronautical Information Publication Norway, revision date 27 October 2005

1.18.3.6 AIP Norway, item 2.7, column H, describes the general uncertainty associated with the use of the SNOWTAM table. See Appendix H.

1.18.4 Sandefjord Airport Torp – winter maintenance instructions

Excerpts from ”Winter maintenance plan for Sandefjord Airport Torp, Winter season 2005/2006, Ground maintenance, Part C, Ch. 4.1” are shown in Appendix I.

1.18.5 EASA certification of contaminated runways

Excerpts from EASA Certification Specifications for Large Aeroplanes CS-25 Book 2, Acceptable Means of Compliance are shown in Appendix J.

1.18.6 Airbus Industrie’s policy

Excerpts from Airbus Industrie’s document “Getting to Grips with Cold Weather Operations”, Airbus Industrie, Flight Operations Support, Customer Services Directorate, 1999, are shown in Appendix K.

1.18.7 Boeing policy

1.18.7.1 The Boeing aircraft factory uses stipulated values for Airplane Braking Coefficient (ABC), which correspond to Airbus’ *”effective μ”*. Boeing does not accept a correlation between the measured (reported) friction values and the aircraft’s ABC or *”effective μ”*.

1.18.7.2 The Boeing standard ABC values, which form the basis for the Airplane Flight Manual landing data, are shown in Figure 3 in Appendix L.

1.18.8 Federal Aviation Administration (FAA) policy

The FAA has issued a Safety Alert for Operators (SAFO) 06012 which describes winter operations. Excerpts from this are shown in Appendix M.

1.18.9 Correlation between measured friction values and the aircrafts’ effective brake coefficients

1.18.9.1 Over the past 50 years there have been many attempts to correlate the measured friction figures with the airplanes’ effective brake coefficients. Airport manager O. Kollerud started the first tests at Oslo Airport Fornebu in the late 1940s. Kollerud (1953) concluded that the airplanes’ ”*efficient μ*” (”*airplane braking coefficient*”, ABC) was 50% of the measured values. The latest correlation tests were conducted in Canada as part of the Joint Winter Runway Friction Measurement Program (JWRFMP 2004), a winter program stretching over several years up to 2004. Figure 2 in Appendix L shows the ABC vs CRFI.

1.18.9.2 Figure 1 in Appendix L shows different correlation curves between measured (reported) friction figures and ”*airplane effective μ*” (or ABC). We see there is little difference between Kollerud’s correlation curve and the Canadian curve. Roughly speaking, the effective friction coefficient is half of the measured and reported one. The figure also shows the ICAO-recommended correlation curve (green) and the Norwegian approved curve (black). The latter is the most conservative, and the one that has proven the most practical over several years on contaminated Norwegian winter runways.

1.18.10 Calculated landing distance

1.18.10.1 Appendix C shows landing calculations performed by MyTravel Airways Scandinavia's Operations Engineering based on Airbus Performance Data.

1.18.10.2 The calculations are based on the ENTO LDA 2 569 m, maximum braking and full use of reverse thrust.

1.18.10.3 The calculations show that ENTO Landing Distance Available (LDA) was long enough; both for the actual landing calculation (ALD) and with EASA margin (LDA + 15%).

1.19 Useful or efficient methods of investigation

No methods of investigation have been used that require a special mention.

2. ANALYSIS

2.1 AIBN's investigations

2.1.1 The Accident Investigation Board has investigated a series of accidents and incidents related to winter operations in recent years (cf. item 1.18.1). Furthermore, AIBN has investigated incidents where there are indications that the operators' procedures might be improved (cf. item 1.18.1.4). As incidents of this category keep recurring at regular intervals, AIBN sees this as a sign of the necessity to keep focussing on improved safety margins.

2.1.2 The Accident Investigation Board is of the opinion that Norwegian winter operations place a lot of responsibility on the airport staff/Airport Supervisors and the flight crews, especially the commanders. This serious incident is a good example on this (cf. items 1.1.5 - 1.1.12). This means that later, especially with the benefit of hindsight, it is fairly easy to say what the Airport Supervisor or the Commander "should" or "should not" have done in order to prevent an accident or an incident. AIBN therefore holds that the investigations ought to comprise the entire aviation transport system. Focus should be on the personnel's assessments in advance of an incident, based on the available information, regulations, knowledge and the general framework conditions at the time of decisionmaking. Based on several investigations of similar incidents, AIBN is of the view that airport personnel, air traffic controllers and pilots, who are expected to accept contaminated runways, do not get the necessary decision-making support in form of realistic rules and regulations and the requisite training.

2.1.3 AIBN has based its investigations and analyses of this serious aviation incident on the theories on accident investigations which are reflected in the works of Reason (1997) and Dekker (2006 and 2007).

> *"Organizational accidents have multiple causes involving many people operating at different levels of their respective companies. By contrast, individual accidents are ones in which a specific person or group is often both the agent and the victim of the accident. The consequences to the people concerned may be great, but their spread is limited. Organizational accidents, on the other hand, can have devastating effects on uninvolved populations, assets and the environment." (Reason 1997).*

"The challenge is to understand why it made sense to people to continue with their original plan. Which cues did they rely on, and why? When cues suggesting that the plan should be changed are weak or ambiguous, it is not difficult to predict where people's trade-off will go if abandoning the plan is somehow costly… People need a lot of convincing evidence to justify changing their plan in these cases. This evidence may typically not be compelling until you have hindsight…" (Dekker 2006).

2.2 Constraints of the analysis

2.2.1 In several of its earlier reports, the Accident Investigation Board has analysed issues with potential of improvements in relation to aviation safety and Norwegian winter operations. In this report, AIBN has looked into matters that have been investigated previously, and matters that are specific to this serious aviation incident.

2.2.2 In its investigation, the AIBN has chosen to analyse the following issues:

- The weather conditions, and weather information received
- Planning
- Assessment of the course of events prior to landing
- Assessment of the course of events after landing
- Survival aspects
- The procedures in My Travel Airways (DK) for operations on slippery runways
- The crew's practice of MyTravel's procedures for winter operations
- Sandefjord Airport's procedures for winter operations
- EASA certification for contaminated runways
- Calculations of landing data
- Winter operations and friction measurements
- Human factors

2.3 Weather conditions and weather information received

2.3.1 Before the take-off from Tenerife (GCTS), the crew received the weather and NOTAM information for ENTO. The weather forecast (TAF) for ENTO was good, but indicated that snow was expected between 1400 and 1600 hrs. local time (cf. item 1.7.2). The forecast for the evening was 4 km visibility in snow with temporary visibility down to 1 200 m and vertical visibility of 800 ft. The crew did not consider these weather forecasts as being especially worrying. They expected the runway to be prepared to the usual acceptable standard during winter conditions (GOOD or MEDIUM). Based on the information available and the crew's experience, the Accident Investigation Board considers that the crew's assessment of the weather conditions was understandable.

2.3.2 Based on the TAF received, the crew expected runway 36 to be operational. However, they received an updated weather and NOTAM report via ATIS during the approach and there had then been a switch to runway 18 (cf. item 1.7.4). ATIS reported dry runway and good braking action. This despite the fact that visibility was 2 500 m in light snow and a dewpoint spread of only one degree (indicating high air humidity).

2.3.3 The crew received ENTO ATIS 1720 UTC prior to their descent towards ENTO. The crew had not received a SNOWTAM. The first SNOWTAM available had been issued at 1450 UTC. This was approx. 3 hours before the estimated time of landing, and therefore of little value.

2.3.4 Based on the available weather information and runway status, the crew did not anticipate any problems with the runway conditions. Only when switching to the tower frequency did the crew receive the first information that the runway had reduced Braking Action. This was around 3 minutes before landing. They were surprised that the runway was contaminated by snow, and therefore became concerned about the possibility of a crosswind combined with reduced friction, and thus requested a wind check. ATC reported that the wind was from 050° 5 kt. This would give approx. 4 kt crosswind and approx. 3 kt tailwind, which was well within the company's limitations. The crew therefore accepted the new runway conditions and that a MEDIUM Braking Action would be sufficient to come to a stop on the available runway. AIBN is of the opinion that the crew assessed the received weather and runway conditions in accordance with the company's procedures. These procedures were based on Airbus procedures and approved by Danish Civil Aviation Authority (D-CAA).

2.3.5 By analysing the moisture- and temperature conditions after the event, it shows that the runway was moist before it became covered by snow (cf. item 1.7.7). The air temperature at 2 m height was measured to be - 1 ºC. (Runway Report at 1451 UTC). During the afternoon the air temperature at 2 m height dropped to - 2 ºC. The dew point spread was 1°C. The air temperature and dew point temperature at the runway surface may be different from those measured at 2 m. The Runway Report at 1741 UTC said that the runway was covered by 8 mm wet snow while the Runway report at 2028 UTC said that the runway was covered by 13 mm dry snow. From this AIBN conclude that the runway started out as a bare and moist runway which gradually was added moisture by snow fall. Combined with a fall in air temperature it is probable that the lower layer of moisture froze to ice at the same time as moist new snowfall was added on top. Hense, it is deducted that when OY-VKA landed the runway was covered by a thin layer of ice with fresh snow fall on top. AIBN consider this illustrates some of the uncertainty regarding decisions wheather the snow is wet or dry. The definitions for wet and dry snow is "the possibility to make a snow ball or not". In relation to the ability to support tire to ground friction these definitions may be useless (cf. Figure 3).

2.4 Planning

AIBN finds that the crew planned its flight operations in accordance with the company's procedures and the received weather report and NOTAM prior to their departure from GCTS. Before their descent to ENTO the approach and landing were planned based on the information received via ATIS.

2.5 Assessment of the course of events prior to landing

2.5.1 The crew started the preparations for approach and landing when they were about 180 NM away from Torp. The crew received the information on the current weather, runway 18 in operation and runway status via ATIS. Based on the previously received weather information they had expected to land on runway 36. However, the reported landing conditions were good, with a dry runway and good Braking Action. The AIBN therefore considers that it was natural for the crew to accept a tailwind component of up to 5 kt.

2.5.2 Based on the estimated landing mass of approx. 72 metric tons, a V_{ref} of 137 KIAS was planned. With the FMGC automatic 5 kt adjustment for the autothrust the V_{app} was adjusted to 142 KIAS. Based on the icing conditions the V_{app} was increased 5 kt to 147 KIAS. Normally autothrust is used during approaches and this will automatically give V_{ref} + 5 kt (VLS) through the FMGC. With hindsight it may be argued that a 5 kt higher landing speed for icing conditions was unnecessarily high considering the light icing conditions and a snow-contaminated runway, and that the FMGC automatically increased of 5 kt would have sufficed. With the information the crew had concerning the runway conditions and GOOD Braking Action, however, the AIBN still finds that the crew's landing planning was reasonable.

2.5.3 The aircraft was configured for a landing from an ILS on passing 2 000 ft (cf. item 1.1.7). When checking into the TWR frequency, about 3 minutes before landing, the crew received information that the runway was contaminated by 8 mm of wet snow. The crew assessed this to be acceptable in view of the MEDIUM Braking Action and with only light crosswind and negligible tailwind. The AIBN supports the crew's assessment based on the information which the crew had at the time. They came out of the cloud cover at around 700 ft and the commander set the Auto Brake (AB) to Medium (DECEL) when passing approx. 450 ft radio height (RH). AIBN's inquiries of incidents related to slippery runways show that pilots ought to use AB Medium or Manual braking when suspecting the runway might be slippery, in addition to limiting the extra speed for landing (Stopping distance $S = V^2/2\mu g$, under 50-60 kt). The stopping distance formula shows that the stopping distance increases with the speed squared. For OY-VKA the 10 kt increase in landing speed (137 + 10 kt) resulted in the stopping distance (S) increasing with 8% (1.077). With an additional 3 kt tailwind, the additional speed for the OY-VKA may have contributed to an approx. 10% (1.1) increase of the stopping distance. From the same formula it can be derived that halving μ ("*effective μ*", or "ABC") will result in a doubling of the stopping distance under 50-60 kt. For OY-VKA this gave an "*effective μ*" of 0.05 (POOR) (a reduction by half from the reported 0.10 stipulated in Boeing's definition, cf. item 1.18.7.2) in a near doubling of the planned stopping distance (S) under 50-60 kt based on standard procedure (cf. item 1.17.3.2). AIBN will point out that the crew followed the company's procedures. It is normal to use the autothrust which automatically increases the V_{app} with +5 kt. The additional +5 kt increase by the crew to compensate for icing conditions is a matter of airmanship and judgement and left to the commander to decide. On the other hand AIBN will caution pilots regarding increased V_{app} during approaches to winter contaminated runways where braking action may be questioned. AIBN wants to underline that the company's procedures were based on Airbus' recommended procedures and approved by the Danish CAA.

2.5.4 During the final part of the approach they came in too high on the glide slope. The commander pointed this out to PF. The PF did not have time to correct this before levelling out, and due to the 10 kt higher landing speed (in relation to the recommended V_{ref} for the actual landing mass), the aircraft "floated" onto the runway for a stretch before touchdown. The OY-VKA landed 357 m ”long” on the runway, 787 m from the threshold, with 140 KIAS. It is easy to say in retrospect that the PF ought to have flown a more precise glide slope and landed the aircraft firmly on the runway in line with the recommended procedure (cf. item 1.17.3.2). The AIBN is of the opinion, however, that a landing speed increase of 5 kt (extra for icing), in addition to the automatic addition for using Auto thrust/Auto throttle (AT) and the subsequent tendency to “float”, fall inside the normal landing margins.

2.5.5 AIBN holds that the crew’s preparations and execution of the approach and landing were within the company’s procedures, viewed in relation to the received information at the time of decision-making.

2.6 Assessment of the course of events after landing

2.6.1 AIBN considers that the crew was not prepared for the runway being particularly slippery, even though they had received information that there was wet snow on the runway and a MEDIUM Braking Action. In retrospect, one might feel that the crew should have responded to the information of wet snow on the runway. The recommended procedure for landing on a particularly slippery runway (or *”limited runway length”)* consisted of braking manually before the nose wheel was lowered to the runway (cf. item 1.17.3.2). AIBN considers that the reason why the crew had not prepared for such a landing procedure was that they were not aware that there would be POOR Braking Action when they had been told MEDIUM. They had thus not reviewed an alternative braking procedure, but based their approach on standard braking using AB Medium. The PF therefore followed the standard procedure by lowering the nose wheel to the runway and using max reverse thrust. The AIBN holds that the crew’s chosen procedure was a natural way to act in the given circumstances.

2.6.2 The crew did not feel any braking action from the wheel brakes. The commander has explained to AIBN that he thought the AB system was malfunctioning. The FDR print-out shows that the AB MED ON was selected on, and that it was reset OFF-ON twice (ref. Appendix B). The first officer registered the commander’s attempts to reset the AB, and chose to switch to manual braking. MyTravel's internal investigation group thinks the reason why the AB DECEL MED did not engage could have been caused by PF applying a certain pressure on the brake pedals on landing. This theory is supported by the first officer admitted habit of landing with his feet resting on the brake pedals and not on the flor when landing. This may have resulted in a late *”spin up”* of the wheels, so that the AB did not engage. The AIBN thinks that a contributory reason could also be that the late *”spin up”* of the wheels was caused by the existence of POOR Braking Action combined with reduced weight on the wheels during the soft landing, and that the required retardation was not achieved. The AB DECEL MED green ON light should have lit up when 80 % (2,4 m/sek^2) of the selected retardation (Medium 3 m/s^2) was achieved. Appendix B shows that the longitudinal deceleration increased only by 0,04 G up to a peak value of 0,20 G (1,96 m/s^2) when the PF employed manual braking. Thereafter the deceleration decreased with decreasing aerodynamic drag. This indicates that the effective braking coefficient (ABC or μ_{eff}) was of the order of 0,04 (POOR). This correlate well with Figur 7. The main retardation force during the first stage of the landing was the aerodynamic drag and engine reverse thrust.

2.6.3 The crew did not sense any effects from the wheel brakes during manual braking. Figure 6 show Airbus’ computer calculation of FDR data and the distribution of braking power in percent from the aeorodynamic drag (mainly flaps and spoilers), reversing, and wheel brakes. The graph shows deceleration from 112 Knots Ground Speed (KGS), and that the drag (air resistance) varied from approx. 50 % just after touchdown, to approximately zero below 30 kt. Reversing contributed approx. 20 % of the total brake force throughout the braking course (disregarding the rolling friction which was negligible). We see that the braking friction varied a lot. This means that the conditions were very slippery and that the anti-skid system was working to the full. The average percentage from the wheel brakes shows a gradual increase from around 20 % at 110 kt to approx. 25 % at around 70 kt where the commander engaged the PB. He did this because he could not feel any effect from the wheel brakes. AIBN has found that this is a common experience for pilots who attempt to brake on a slippery surface (Braking Action POOR).

2.6.4 Figure 7 shows the Airbus' computer calculation of the airplane braking coefficient" (ABC, or *"effective µ"*). The graph also shows that the average braking coefficient was approx. 0.05 from approx. 110 kt down to approx. 70 kt. That is the speed at which the commander engaged PB because he did not sense any braking actions from the wheel brakes (ref. Figure 6). Figure 7 shows that the ABC fell from approx. 0.05 to 0.04 when the PB was turned on. This is compatible with the friction theory and a result of the anti-skid system being disconnected. This caused the wheels to lock, and the friction changed over to a pure gliding friction which is lower that a slip friction. Figures 6 and 7 further show the effect of the commander's turning left by means of the nose wheel steering. Thereby the aircraft's nose turned gradually towards the left while the aircraft mass velocity vector continued along the same runway path. The friction from the main and nose wheels, which were then skidding more and more sideways along the runway direction through the snow, gradually increased up to 0.06-0.07, and up to approx. 0.08 at the end.

2.6.5 Appendix B shows that the aircraft had a soft touchdown with several seconds passing between the time the main wheels made contact with the runway and until the main wheels' *"weight on wheels"* switches *("squat switches")* were operated. AIBN considers that the reason PF did not perform a firm landing as recommended for landings on slippery runways, was because this had not been briefed. As shown in the analysis in item 2.5.2, the crew had planned for a landing on a bare runway with good Braking Action. Appendix B shows that braking started at soon as the "*squat"* switches were operated (*"weight on wheels"*). With weight on wheels and the throttles idling, the spoilers are activated. At the same time the PF responded quickly by putting the engines in reverse. Appendix B shows that the deceleration quickly reached 0,16 G and increased to only 0.20 G. when the PF applied manual brakes. The print-outs further show that even though 8 seconds passed from landing until PF engaged manual brakes, the deceleration contribution from the wheel brakes were insignificant. Compared with Figure 6, Appendix B shows that the wheel brakes only contributed an estimated 20 % braking action (equivalent to an ABC of 0.20 G times 0.20 % = 0.04) down to approx. 70 kt. Therefore, the late engagement of manual braking was without any significant importance with the actual runway conditions. Figure 6 and Appendix B show that with a relatively constant braking power from the thrust reversal, the whole braking power diminished. AIBN therefore holds that it was not unreasonable for the crew, who was expecting MEDIUM Braking Action, to suspect brake failure under the circumstances in question. On the other hand AIBN points out that the correct procedure for landing on slippery runways was to fly a stabilised approach on the glide slope with a firm landing and start of manual braking before the nose wheel contacted the runway. Operations on contaminated runways leave the crew with reduced margins and higher risk of runway excursions than operating on dry runways. It is therefore important that the crew use the optimum landing and braking procedures as specified by the manufacturer and the company.

2.6.6 At the time when the commander took over control (PF), the aircraft was halfway down the runway. The FDR print-out shows that the AB MED DECEL switch was on as expected, but the Green DECEL light was not lit and the braking did not start before the first officer applied manual braking. The FDR data show that the full engine reverse was maintained the whole time until the aircraft stopped, and that 80 % of the selected deceleration was not achieved. 80 % equals 2.4 m/s^2 while only 1.96 m/s^2 decelration was obtained.

2.6.7 The commander used the resources available to him with a full thrust reversal and max manual braking. Despite this, the braking action was POOR and the crew realised that they would be unable to stop on what was left of the runway. The commander suspected a failure of the braking system, and felt that he had to attempt an alternative braking method. He therefore engaged the Park Brake (PB). The FDR printout shows that PB was on from 73 kt GS until the aircraft stopped.

2.6.8 Use of PB on suspicion of brake failure is the last point in the prescribed procedure (cf. item 1.17.3.3). The procedure specifies several points to go through before engaging PB. The AIBN is of the opinion that there was not enough time to go through the full procedure and the commander's action was understandable under the circumstances. For use of the prescribed alternative braking procedure, the anti-skid and Nose Wheel Steering (A/SKID & N/W STRG) shall be turned off. This procedure is developed from certification testing on dry runways, and not for braking on surfaces with POOR Braking Action. By using PB the nose wheel steering is maintained. Thereby the commander succeeded in turning the aircraft's nose to the left. Figure 6 shows that the braking force from the wheel friction gradually increased from approx. 50% at 60 kt ground speed to approx. 80% towards the end of the braking. From 20 to 0 kt GS the total retardation force consisted of 20% thrust reversal and 80% friction from the tyres *("skidding")*. This effect is clearly shown in Appendix B, where we see that the lateral deceleration is significantly increased towards the end of the braking. This began when the commander turned the aircraft's nose to the left at approx. 60 kt (see Figures 6 and 7). This meant that all three wheelpairs (main and nose) skidded sideways with their broadside in the direction of motion and ploughed through the snow. This meant that the total friction surface was greater than if only the two main wheels were to skid with locked wheels in the direction of motion. For the last 5 seconds of the braking, the deceleration due to this transverse position of the aircraft was 1.5 times as much as the total deceleration above 80 kt GS.

2.6.9 At this point of time it was clear to the crew that they would end up outside the runway. The first officer, who was now PNF, saw that the terrain on the eastern side of threshold 36 was somewhat more level than to the west. He advised the commander to steer towards the left (eastern side of the runway). The aircraft skidded on locked wheels, and by turning the nose wheel to the left, the commander initiated an unintended, but, as AIBN sees it, a favourable swing of the aircraft's nose to the left. The low friction meant that the aircraft's nose turned towards the east, while the aircraft's velocity vector continued forwards along the runway.

2.6.10 Radio communication print-outs show that the crew called up the TWR with the words: *"we are going off the runway"* approx. 40 seconds before the aircraft stopped at the end of the runway. At that time the air traffic controller was engaged in a conversation with the Airport Supervisor, and a phone call from Farris Approach came in at the same time. He therefore did not catch the message. The air traffic controller asked for a repeat of the message from OY-VKA. A confirmation of an emergency was repeated by OY-VKA, and the following was added: *"we need rescue"*. The AIBN considers that this indicates that the crew had a good understanding and situational awareness of the situation, which contributed to the rapid emergency response.

2.6.11 OY-VKA continued to turn the nose towards the left while the mass velocity vector was skidding towards the end of the stopway at the southern end of the runway. In this area, the runway slopes a bit downwards to the southwest. Because of the low friction and the sloping runway, the aircraft gradually skidded over on the right hand side of the centre line. The reverse thrust of the engines contributed to this, as they were still on maximum thrust reversal.

2.6.12 AIBN considers that the crew handled the emergency situation in which they suddenly found themselves in, in a satisfactory manner. In hindsight, it might be argued that based on the TAF and METAR, they should have been prepared for reduced Braking Action on the runway. AIBN considers such viewpoints as "counterfactual", and that one must base the analysis of the situation on the knowledge the crew had on the available runway status.

2.6.13 In hindsight, the crew could also be criticised for having employed a wrong alternative procedure for what they though was a brake failure. AIBN considers that this must be judged based on the situation they found themselves in. The aircraft quickly neared the end of the runway, and the crew feared skidding off the runway. The commander only had a few seconds to try to limit the damage of a runway excursion. There was no time to perform a full and complete alternative braking procedure. Furthermore, AIBN considers that the prescribed alternative braking procedure was based on landing on a dry rynway and would not have improved matters.

2.6.14 The commander made optimum use of his available resources. He kept the maximum thrust reversal, engaged PB and turned the aircraft's nose towards the left, following the first officer's (CRM) directions. AIBN considers that using PB was the best choice under these particular circumstances. Using PB allowed him to maintain the nose wheel steering, while the alternative procedure would have disconnected this. By steering left in order to run off the runway on the left-hand side, the commander initiated skid of the aircraft, making it skid more and more in a traverse direction on the runway. Appendix B shows how much more deceleration this gave, in that Lateral G increased a lot more than Longitudinal G decreased, resulting in a full stop of the aircraft at the very end of the concrete strip. The last movement of the aircraft's sideways momentum came to a stop as the nose wheel hit the concrete based at a speed of 2-5 kt GS.

2.6.15 In AIBN's assessment, the crew were in an emergency situation, with no clear emergency procedure to relate to. Time was of the essence and the commander, together with the first officer, did what he felt he was able to do to mitigate the damage. AIBN considers that the crew was able to save a highly critical situation in a satisfactory manner. It is further the opinion of AIBN that in a stressful emergency situation, for which there are no clear procedures or no simulator training, the airmen will react on the basis on their experience and training such as in this incident.

2.7 Survival aspects

2.7.1 Fire and rescue

2.7.1.1 The radio and CVR communication recordings show that the crew twice radioed an emergency alert on the tower frequency before the aircraft came to a stop. The first message was not interpreted by the air traffic controller and the crew made a second call. In addition they informed about a runway excursion and needed rescue equipment *(”we need rescue”).* Thus, the air traffic controllers were aware of the emergency situation before the aircraft stopped. Based on this, the emergency alarm was triggered, and the emergency response vehicles were on their way while the aircraft was still moving. AIBN’s investigations show that 10 seconds elapsed from the time the ATC controller received the second emergency transmission until the alarm was triggered. This time delay had no consequence for this incident but AIBN wants to underline the importance of the rescue alarm to be triggered at the first sign of an emerging emergency situation.

2.7.1.2 The air traffic controller on duty alerted the fire and emergency rescue crew who responded immediately by scrambling the rescue vehicles; one duty vehicle and three fire trucks. The first fire truck was in position by the aircraft 109 seconds after the alarm, and the last vehicle was in position 127 seconds after the alarm was triggered. This is outside BSL E requirements of the 90 to 120 seconds response time. On their way out, the Airport Supervisor told the drivers to drive carefully due to the very slippery driving conditions. When they reached the aircraft, the Airport Supervisor conducted an inspection around the aircraft and reported the observed damage back to the TWR. The emergency response time at this incident was 19 seconds more than the minimum required, and 7 seconds more than the maximum limit for arriving in position at the aircraft. Of this delay 10 seconds was in the triggering from the TWR. The remaining delay was caused by the slippery driving conditions forcing the rescue vehicles to drive carefully. Based on this AIBN considers that the fire and rescue service performed in a satisfactory manner.

2.7.2 Evacuation

2.7.2.1 The CVR shows that the crew were unable to warn the cabin crew and the passengers of the potential excursion as prescribed by the procedures (*”brace for sudden stop”* or similar). The crew was fully occupied with damage limitation by trying to stop the aircraft on solid ground, while also calling TWR twice. AIBN is of the opinion that this was a priority the crew had to make in a few split seconds in a highly stressful situation, and agrees with the crew’s order of priority. Everybody in the cabin were strapped into their seatbelts, and the aircraft’s ground speed was so small when it finally stopped, that neither the cabin crew nor the passengers were exposed to any extra large forces (ref. FDR data Appendix B).

2.7.2.2 Once the aircraft came to a standstill, the commander conferred with the cabin chief and was told that all was well inside the cabin. He decided to hold the evacuation of the aircraft until buses had been supplied by the airport. The crew started up the APU and shut down engines. Due to snowy weather and slippery roads, the buses were delayed and the passengers were only evacuated approx. one hour after the plane stopped. Eventually a staircase was transported out and the passengers were evacuated by the left cabin door at the front (cf. Figure 3). AIBN finds that the crew handled the evacuation in a satisfactory manner.

2.8 MyTravel Airways Scandinavia's procedures for operations on slippery runways

2.8.1 MyTravel Airways' procedures are based on the Airbus recommended procedures for winter operations. AIBN has previously investigated an incident with an Airbus A320 belonging to My Travel Airways UK at Harstad/Narvik Airport Evenes (ENEV) on 24 November 2004 (AIBN report 2007/25, Reference 3). Based on the incidents at Evenes and Torp, and also on several other investigations of accidents and incidents related to slippery runways, the AIBN has drawn the conclusion that the method recommended by Airbus for evaluating "*effective μ"* is less satisfactory.

2.8.2 Item 1.18.6 and Appendix K deals with Airbus' policy concerning friction on contaminated runways. As will emerge from the text, Airbus does not trust friction measurements. This is partly in line with the FAA's and Boeing's view. However, Airbus' view is based on a theory that every type of contamination results in a particular friction. This view is in part based on EASA's CS-25 Book 2 (cf. item 1.18.5 and Appendix J) which describes the use of *"default values"* for *"effective μ".* AIBN's findings in its investigations indicate that these fixed friction values are not correct.

2.8.3 Appendices D to F show the Airbus/MyTravel procedures for operations on contaminated and slippery runways. Appendix D-1 shows Airbus's definitions for the different types of contamination. As can be seen from the appendix, Airbus operates with the term *"fluid contaminated runways"* in which specified quantities of dry snow, wet snow, slush and water, are equalled to a wet runway. AIBN has found in several investigations, that this does not correspond with the real world. Empirical data shows that a wet runway has an *"effective μ"* of about half the friction of a dry runway. Boeing has conducted tests with their aircraft types which show that the ABC (corresponds to Airbus' *"effective μ")* is in the region of 0.40 on a dry runway, while ABC on a wet runway is around 0.20, and corresponds to Braking Action GOOD (cf. item 1.18.7 and 1.18.9). In several investigations, AIBN has found that even small quantities of dry or wet snow or slush on the runway has resulted in a POOR Braking Action.

2.8.4 Appendix D-2 shows that Airbus equals friction on specified depths of dry snow and wet snow with specified depths of slush. Appendix D-2 shows that Airbus equals 12.7 mm wet snow and 50.8 mm of dry snow with 6.3 mm slush. In several investigations, AIBN has found that this method does not measure up with the realities. Take the relevant incident at Torp as an example. The status said 8 mm wet snow on the runway, which is less than 12 mm. Based on the information in the Airbus FCOM/MyTravel Performance Manual (ref. Appendix D-2), the crew of the OY-VKA, chose to make a conservative calculation by equalling 8 mm wet snow with 6 mm slush. Appendix E-1 shows MyTravel Performance Manual data in the form of Gross Mass Chart for ENTO (dated 19 April 2006). As can be seen from this, an A321-211 can land on ENTO runway 18 with a slush cover of 6 mm, in 10 kt tailwind and with a 15% margin, up to a landing weight of 88 637 kg. In comparison the OY-VKA had a landing mass of 71 800 kg. AIBN consider these examples an indication on the uncertainty in using the "fluid contaminant" theory in establishing effective braking action (cf. items 2.8.5 and 2.8.6).

2.8.5 Appendix E.2 shows a table from MyTravel Performance Manual which gives Gross Mass landing data for an A321-211 landing on ENTO runway 18 with a measured friction (FC) (dated 19 April 2006). The table shows that the OY-VKA should have been able to land with a 5 kt tailwind with a measured (reported) FC of 0.25 with a landing mass of 79 024 kg (actual mass was 71 800 kg).

2.8.6 Appendix F shows a table from the Airbus FCOM/MyTravel Performance Manual for use during flying for calculating the relevant landing distance by means of manual braking (without using AB). The table shows that for landing on a runway covered with 6.3 mm of slush and a 72 000 landing mass, an A321 will require 1 715 m without reserve. The landing distances are based on the correct V_{ref} value which is calculated by the aircraft's computer. The table provides correction values for tailwind and reverse thrust. It shows that 10 kt tailwind adds 22% to the stopping distance, while use of reverse thrust gives a deduction of 11%. The total correction becomes an addition of 11 %, giving a landing distance of 1 715 m x 1,11 = 1 904 m.

2.8.7 The three Airbus methods for calculating landing data show that there was nothing in the way of landing at Torp at the time in questions. The methods discussed under item 2.8.4 and 2.8.6 are based on Gross Mass Charts and available runway (Landing Distance Available, LDA), which has been set to 2 569 m for ENTO RWY 18. The method furthermore presupposes a certain friction *("effective μ")* which Airbus has determined for a certain *"equivalent contamination"*. In an earlier investigation, the AIBN has found that this method is not reliable in practice (see Reference 3).

2.8.8 The method under discussion in item 2.8.5 is based on the measured (reported) FC. In several investigations (see AIBN RAP 2009/7, AIBN RAP 2009/6, AIBN RAP 2007/25 and AIBN RAP 23/2002, References 1-4) the AIBN has proven that use of measured FC values are not reliable for contaminations in the form of new snow, wet snow and slush (defined as "wet" contamination). AIBN's investigations show that use of measured FC only can be used for dry, compact snow or dry sanded ice. The AIBN's investigations also show that "wet" contamination results in POOR braking action. The AIBN is therefore of the opinion that the method of setting the friction for certain maximum quantities of dry snow and wet snow to be equal with the friction for "slush" is unreliable (cf. item 1.18.7.1 Boeing). In order to accommodate for the documented uncertainties in the measurements (cf. item 1.18.2.1, and item 1.18.2.3), the AIBN is of the opinion that the safest method is to use measured or predicted values for GOOD, MEDIUM or POOR Braking Action for all types of contamination, and not trust that a certain quantity of snow or slush will give a certain friction or can be equalled to a certain quantity of water.

2.8.9 The AIBN holds that the practical use of FC should be limited to the values shown in Table 4 below. The first column in the table describes the runway status. AIBN is of the opinion that runway status should be restricted to the main categories of dry, wet and contaminated runway.

Table 4: The Accident Investigation Board's assessment of the pratical use of FC.

RWY status	Jet ABC	Prop ABC	SNOWTAM	ICAO Code	
Dry	0.40	0.40			
Wet	0.20 or TBD	0.20 or TBD			
Cont FC					
0.40	0.20	0.20	Good	5	
0.30	0.10	0.15	Medium	3	
0.20	0.05	0.10	Poor	1	Wet/Moist conditions

2.8.10 AIBN is of the opinion that the classification of contaminated runway should be limited to three friction categories; GOOD, MEDIUM and POOR, to be used with ICAO SNOWTAM FC values (0.40, 0.30 and 0.20), and which can be fed into the Cockpit Performance Computer (CPC). Column 2 (jet) and 3 (prop) show practical use ABC (*"effective µ")* which can be used in the CPC calculation model.

2.8.11 Based on the analysis above, the AIBN is of the opinion that MyTravel Scandinavia (now Thomas Cook Airlines Scandinavia) should reconsider the use of Airbus' recommended method of equalling friction on different types of contamination. In several investigations, the AIBN has ascertained that the friction of wet/moist contamination of the types new snow, wet snow and slush has been found in experience to be POOR.

2.8.12 During the hearing prossess of the draft report it has been raised concern that an airline may not deviate from the manufacturer's advice and operating procedures. AIBN agrees in pricipal, but wants to point out that landing performance data for contaminated and slippery runways are advisory information only. An airline may use more conservative data approved by the local aviation authority based on own risk assessments. AIBN points to the facts that the jet aircraft are certified based on test data from takeoff and landings on dry runway without use of engine reversers and within 60 % of LDA. Based on this the maximum certified landing masse for Airbus 321-211 OY-VKA on dry runway was 77.000 kg (cf. item 1.6.4). In spite of this EASA approves A 321 operations on contaminated and slippery runways with landing mass up to 100.000 kg. To AIBN this is a clear indication that the safety margins for operations on contaminated and slippery runways are less than for operations on dry runways. Another indication is that operations on dry runways are based on certified data while operations on contaminated and slippery runways are based on advisory data not substantiated by test data.

2.9 The crew's practice of MyTravel's procedures for winter operations

2.9.1 Flying in icing conditions

The crew acted in accordance with MyTravel's procedures for winter operations (cf. item 1.17.3.1). The procedure states that if *"significant ice accretion"* is observed, the recommendation is to increase V_{ref} (V-Landing Speed, VLS) by 5 kt when using full flaps. The crew chose to do this although no significant icing was reported. This is a concideration of the commander based on airmanship and procedures. In retrospect it may be argued that the automatic increase of 5 kt to the landing speed by use of Auto Thrust should have sufficed. The procedure further recommends increasing the Landing Distance Required (LDR) by 10%. The increase in speed of 5 kt came in addition to the 5 kt which gets added automatically by the FMGC when using the Auto Thrust (AT). A 5 kt faster landing speed increased the required landing distance by approx. 7 %. AIBN considers that the selected speed was in accordance with the company's procedure, and it was natural for the crew to not place particular emphasis on the landing speed with regards to a very slippery runway. They had planned the landing based on the information received that the runway was bare, with GOOD Braking Action. Upon receiving information of MEDIUM braking action 3 minutes before landing they made an assessment as to whether they could land under the prevailing conditions, and found that this was acceptable. AIBN can appreciate that assessment.

2.9.2 Landing on contaminated runways

2.9.2.1 The procedure for landing on contaminated runway is referenced in item 1.17.3.2. The procedure recommends using AB MEDIUM. This was also used by the crew. In hindsight it is easy to see that the crew should have briefed and performed a landing on contaminated runway as per the recommendation. Based on the information available to the crew, AIBN is of the opinion that it was not clear to the crew that the runway had POOR Braking Action.

2.9.2.2 In this case, the crew followed the applicable procedures for determining the landing speed. AIBN has, however, in several investigations noticed that an unnecessarily extra speed is added to the recommended landing speed. It might seem that the pilots are unnecessarily worried about having a too low speed during landing. It seems that this worry overshadow any worries about being able to brake on a slippery runway. In this case, the crew had a 10 kt high landing speed in relation to the basic V_{ref} based on landing mass alone. Of this speed increase 5 kt was automatic due to Auto Thrust, and hence not by crew choice but a result of standard procedure. The other 5 kt was chosen by the commander due to icing conditions. These speed additives in combination with a high flare and soft landing, meant that the aircraft landed 357 m further in on the runway than desirable (total 787 m). The recommended landing on slippery runways is a firm landing with positive touchdown (cf. item 1.17.3.2). In this case they landed the aircraft with a + 10 kt + 3 kt tailwind = 13 kt higher landing speed than the recommended basic V_{ref}.. This was a 10% increase in landing speed which resulted in a 21 % longer stopping distance. In several investigations involving runway excursions following landings on slippery runways, the AIBN has noticed that flight crews tend to add to the speed beyond the recommended measures. In this incident the crew followed the airlines' procedures regarding use of Auto Thrust and flying in icing conditions. The resulting V_{app} of 147 kt was therefor acceptable. On the other hand AIBN consider that it is important that crews pay special attention when landing on contaminated runways and reconsider use of Auto Thrust and speed increases due to icing. The challenge of stopping on a contaminated and slippery runway may be of higher concern than using too low V_{app}. The Accident Investigation Board will advise flight crew in general to reassess the need for increasing landing speeds when landing on wet or contaminated/slippery runways.

2.9.3 Loss of wheel brakes

The procedure for brake failure is found in item 1.17.3.3. The crew had selected AB Medium. They did not sense any effects from the wheel brakes after landing. They also observed that the selection switch for Auto Brake was not lit as it should be. The PF then chose to perform a manual braking procedure, but the crew did not feel any increased braking action from the wheel brakes. The commander consequently suspected a brake failure and chose PB. As can be seen from item 1.17.3.3 the recommended procedure for brake failure is relatively elaborate when considering that the aircraft is halfway down the runway. In addition, the procedure prescribes disconnecting the Anti-skid and Nose Wheel Steering. If all of this fails, the PF should engage the PB. The commander decided to go to PB directly. AIBN is of the opinion that it is understandable that the commander suspected brake failure. Most pilots will interpret POOR braking action to mean brake failure if they were expecting something better (GOOD or MEDIUM). AIBN further holds that the course of action chosen by the commander, in engaging PB, was the best action he could have taken in the relevant and highly critical situation. The procedure for brake failure is based on tests performed during the certification for the airplane type. Such certification is performed on a bare and dry runway with good friction. Under such circumstances the need for nose wheel steering is not the same. The commander thereby kept control over the nose wheel steering, which he would not have had, had he followed the recommended procedure. Thus, the commander was able to turn the aircraft towards a more suitable area for a controlled excursion. This was not successful because the aircraft skidded on locked wheels along the same velocity vector. On the other hand the commander's steering caused the aircraft to swerve and skid sideways. This provided an increasing sideway friction, which resulted in braking the speed of the aircraft on the remaining runway strip, and the commander thus was able to prevent the excursion. The AIBN will complement the commander for his determination and ability to act in a stressful situation which could have ended up far worse.

2.10 Sandefjord Airport's procedures and application for winter maintenance

2.10.1 Winter maintenance regulations

2.10.1.1 Excerpts of the regulations relating to winter maintenance at Sandefjord Airport Torp (ENTO/SLAS) are included in item 1.18.4. and Appendix I. As can be seen from these, the airport had an expressed *"black runway philosophy"*. This means that the company prioritised traffic and runway treatment such that it in practice should be able to offer a runway free from snow or ice. It can furthermore be seen that sweeping and removal of snow, slush and ice from the runway were to take place as speedily as possible. If friction was to be measured, the conditions must be inside the measurement device' area of application and measurements must be taken in a continuous sweep of both runway directions. With regard to friction measurements the procedure stated that it was difficult to report friction figures during wet snowfall or slushy conditions, and that a new runway report must be prepared which gave the depth of snow and friction level 9 under these conditions (see Appendix H). In such a case, the procedure did not permit the use of friction measurements.

2.10.1.2 AIBN finds Sandefjord Airport Torp's regulations for winter maintenance were satisfactory in the sense that they reflected the Norwegian regulations in AIP Norway and BSL E. On the other hand this incident is an example of that it was difficult to adhere to the specified procedure during daily and hectic traffic situations. AIBN will advice

ENTO/SLAS to review the training programs for the airport personnell in order to improve the correlation between the instructions and the performed actions.

2.10.2 Performance of winter maintenance

2.10.2.1 AIBN has investigated several accidents and incidents related to slippery runways over the past 10 years (cf. item 1.18.1). From these investigations, AIBN has noted that it is difficult for the airport services personnel to comply with all the requirements they are faced with. AIBN further holds that the regulations are so comprehensive and difficult to adhere to in practice that they in fact cannot work as they were intended to. This is especially relevant for times when conditions change constantly due to sustained precipitation and for wet conditions (cf. item 2.10.2.4). AIBN has also noted that it is easy in hindsight to say what the personnel should or should not have done with regard to the complicated regulations. Based on many investigations into these matters, AIBN draws the conclusion that international and Norwegian regulations are based on vague facts, which has produced highly simplified physical models which do not have a sufficient basis in reality. The AIBN finds that there is not sufficient grounds for criticising the personnel who try their best to comply with a complicated set of rules and regulations.

2.10.2.2 In the relevant case at ENTO the available reports show that the personnel at Sandefjord Airport Torp "fell behind" in their treatments for sweeping the runway. A large part of the reason for this was the continuous questions from ATC and another operator and their handling company as to whether they could use the runway before treatment had been initiated. In the opinion of the AIBN, this illustrates some of the problems. Even though the rules are clear when it comes to responsibilities, there is always a certain "production pressure", to the effect that all parties involve want the traffic and passengers to be as little delayed as possible.

2.10.2.3 In the case of the incident in question, a sweeping was planned as the Airport Supervisor had ascertained that there was too much snow on the runway. This was postponed due to traffic considerations. In the meantime a decision was made to perform a friciton measurement with BV-11. Because the OY-VKA had been cleared for approach and landing, there was not sufficient time to execute a continuous and uninterrupted friction measurement of both sides of the runway in both directions. The measurements had to be interrupted, and the friction figures communicated to OY-VKA were incomplete measurements. The crew related to the friction figures that were read to them and understood the friction to be MEDIUM. This was reported as 8 mm wet snow. Based on the wishes from Norwegian airline companies, the Norwegian regulations for reporting contamination depths have been changed compared with the recommended values from ICAO (cf. Appendix H and item 1.18.3.3-1.18.3.4). The reason for this is the uncertainty of the measurements and in order to make the measurements seemingly more accurate. The Norwegian measurement intervals are 6 mm for wet snow. The depth of snow on Torp (8 mm) should therefore have been reported as 12 mm if the snow was wet. AIBN does not think that the Norwegian limits for measuring depths contribute anything towards an improved accuracy or higher safety. AIBN feels that the original ICAO intervals which had 3 mm for slush, 10 mm for wet snow, and 20 mm for dry snow, account for a higher degree of conservatism. On the other hand, the practical impact of either one of the reporting methods is of little importance. AIBN's investigations indicate that it is difficult even for meteorologists to state whether newly fallen snow is wet or dry. AIBN's expert meteorologist[3] says that all newly fallen snow contain a relatively high degree of moisture (Mook 2006). Which is why newly fallen snow, on substrata of existing snow or ice will be slippery. Based on AIP Norway (cf. item 1.18.3.5), the approved measuring range of the BV-11 was limited to 3 mm wet snow and 25 mm dry snow. The reported snow depth of 8 mm wet snow was by definition outside the measurement application of BV-11. AIBN's former investigations (cf. item 2.8.8 and AIBN RAP 2009/7, AIBN RAP 2009/6, AIBN RAP 2007/25, AIBN RAP 23/2002, see References 1-4) indicate that friction measurements on a moist contaminated surface are useless regardless of the depth of the contamination. The moisture content depends partly on the air and dewpoint temperature. AIBN's investigations further show that contaminations are particularly slippery when the difference between the air temperature and dew point is very small; less than 3 K dew point spread. AIBN is of the opinion that the erroneous reporting in this case had no impact on the course of events. Even if there had been only 3 mm of wet snow, the surface would still have been slippery in the prevailing conditions. However, the AIBN will still point out that in this instance, the friction measurement device was used outside its approved measuring range and the unreliable friction numbers transmitted to the crew (cf. item 2.10.2.6).

2.10.2.4 The Norwegian definitions of the different types of contamination are shown in item 1.18.3.2 and Appendix H. Appendix D-1 show Airbus' definitions. By comparing the Norwegian definitions with Airbus' definitions, we see that they have different specific weights. AIBN sees this as an example of the uncertainty that applies to contaminated runways and that the so-called "experts" are not in agreement. AIBN therefore holds that it is unreasonable to instruct Airport Supervisors to differentiate between dry and wet snow, and between wet snow and slush without scientific methods. The consequences for defining the contamination as the one thing or the other can be considerable, when translated into different friction coefficients (Mook 2006).

2.10.2.5 AIBN considers that it was practically insignificant that only an incomplete friction measurement had been performed. The figures would most probably have not been any different if the measurements had been completed as they should have been. In several investigations, the AIBN has pointed out the uncertainty of friction measurements (cf. item 1.18.3.6 and Appendix G). Furthermore, AIBN has established that wet conditions and small dewpoint spread result in poor Braking Action. The situation at Torp on 26 March 2006 illustrates this.

2.10.2.6 To the degree there are lessons to be learnt from this incident when it comes to how the regulations are put into practice, the AIBN thinks that the airport personnel and ATC personnel should accept delays in traffic to a higher degree and try to be proactive. This means that when a situation involving difficult weather and surface conditions is under way, there are some unpopular decisions that need to be taken. In practice, this means that the airport must be closed for runway treatment, with the air traffic put on hold or diverted to an alternative airport before the runway conditions fall outside the acceptable criteria.

2.10.2.7 During the landing OY-VKA collided with a concrete antennae basement which protruded above the runway surface at the very end of runway 18. AIBN consider this a safety obstacle and has issued a safety recommendation to this effect.

---

[3] Meteorologist Professor (Ret) R. Mook, PhD

2.11 EASA certification of contaminated runways

2.11.1 Excerpts from EASA CS-25 Book 2 Large Aeroplanes

Item 1.18.5 and Appendix J refer to excerpts of EASA's certification rules for contaminated runways.

2.11.2 Braking Friction (All Contaminants)

2.11.2.1 EASA permits use of what they call *"minimum conservative "default" values"* as shown in Table 2 of Appendix J, in addition to relying on test data for *"Aeroplane effective μ"* (or ABC). At the same time, EASA maintains that *"default friction values"* as shown in Table 2 are "conservative" values. Based on our investigations of accidents and incidents over the past 10 years, AIBN considers that the stated *"default"* values for ABC *("effective braking coefficient")* are not conservative, but rather optimistic. EASA gives ABC for wet snow of less than 5 mm depth equal to ABC for wet snow regardless of depth, and dry snow below 10 mm equal to dry snow regardless of depth. In AIBN's opinion, this is not true in practice. An ABC of 0.17 is almost the same as GOOD (see Appendix L). Experience from Norway shows that new snow and wet snow with no sanding result in a POOR Braking Action. EASA gives an ABC for compacted snow of 0.20 and an ABC of 0.05 for ice. These values were arrived at by Kollerud's testing on Fornebu (Kollerud, 1953). The values have been verified by several subsequent test programmes, and are the only ABC values with apparent international agreement. The AIBN considers that experience show that these values are fairly correct under winter conditions that are dry and with many degrees of frost, but that they are not good enough for wet conditions and with dewpoint spread of less than 3 K, or when the temperatures lie around freezing point. This was established already during the above-mentioned tests at Fornebu.

2.11.2.2 AIBN considers that the EASA recommended (*"default values"*) may be acceptable for take-off calculations, based on the minimal likelihood of an interrupted take-off. Despite of this, AIBN wants to warn that an interrupted take-off with friction values such as the ones shown in Table 2 of Appendix J in reality have very small chances of stopping an aircraft on the remaining part of the runway. AIBN's investigations have shown that contamination as shown in Table 2 in Appendix J, which gives an ABC of 0,17 but might actually be only half (0.08). The runway status on ENTO at the time of the incident was reported to be 8 mm wet snow. According to the Norwegian regulations at the time wet snow should have been reported in 6 mm intervals. 8 mm wet snow should therefore have been reported as 12 mm. As will appear from item 1.18.3.1 and Appendix H, the former reporting intervals were 20 mm for dry snow, 10 mm for wet snow, and 3 mm for slush, and that these should be rounded up. These rules were based on ICAO's recommendations. We here see that the international recommendations were more conservative that the Norwegian ones. The reason for the Norwegian difference from the international reporting was that Norwegian airline companies wanted to have reporting intervals that corresponded with their own procedures. The EASA *"default value"* in Table 2 in Appendix J gives an ABC value for wet snow of 0.17. In the relevant case it was approx. 0.05. This is less than a third, which would give a tripling of the stopping distance below "reverser cut out" speed (50-60 kt). This shows how serious such physical simplifications are.

2.11.2.3 AIBN holds that EASA's *"default values"* other than for compacted snow and ice are highly uncertain, and should not be used.

2.11.2.4 Appendix K is an excerpt of Airbus' policy concerning operations on contaminated runways. Airbus defines the contamination types as *"hard contaminants"* and *"fluid contaminants"*. AIBN will refer in particular to the term *"fluid contaminants"*:

> ***"Fluid contaminants***
>
> *Airbus Industrie provides takeoff and landing performance on a runway contaminated by a fluid contaminant (water, slush and loose snow) as a function of the depth of contaminants on the runway.*
>
> *For instance, takeoff or landing charts are published for «1/4 inch slush», «1/2 inch slush», «1/4 inch water» and «1/2 inch water». For loose snow, a linear variation has been established with slush."*

2.11.2.5 Airbus Industrie's definitions are based on the EASA certification rules (cf. item 1.18.5 and Table 2 in Appendix J) which the AIBN is sceptical to. It appears that Airbus assumes a linear correlation between the different types of contaminations' specific mass and friction which AIBN does not think is based on scientific data.

2.12 Calculation of landing data

2.12.1 <u>MyTravel Airways Scandinavia</u>

Item 1.18.10 and Appendix C show MyTravel's landing calculations based on three (3) different Airbus approved methods. All calculations show that OY-VKA should have stopped on the remaining runway if the friction had been as predicted.

2.12.2 <u>AIBN's assessment of the calculations</u>

2.12.2.1 AIBN's assessment of MyTravel's procedures is discussed in item 2.8. MyTravel's figures differ only insignificantly from AIBN's figures. The difference comes as a result of MyTravel using Airbus' calculation program. AIBN has used the data of Appendix D-F, which are representative for the data which was available to the cockpit crew.

2.12.2.2 AIBN finds that this incident convincingly illustrates how uncertain landing calculations can be when they are based on Airbus' *"fluid contaminants"*.

2.12.2.3 At the same time, this incident confirms the view of the AIBN that one must not rely on friction measurements (FC) when METAR shows snow falling (new snow) and the dewpoint spread is below 3 K. Under such conditions the AIBN investigations show that the Braking Action ought to be reported as POOR or UNRELIABLE. In addition UNRELIABLE should be used in all cases where the contamination exceeds the friction meters measuring limits.

2.12.2.4 AIBN also holds that the incidents supports the AIBN viewpoint that the safest method for determining friction of contaminated runways is through a combination of friction measurements where FC is rounded down to 0.40, 0.30 and 0.20, and a discretionary evaluation of the friction as POOR with wet contaminants and with a dewpoint spread of less than 3 K. The ICAO SNOWTAM table allows for using the intermediate levels between GOOD, MEDIUM and POOR. By downward adjustment of measuring values to the nearest round value (0.40, 0.30 and 0.20) some of this insecurity will be reduced (cf. item 2.8.9 and Appendix G, Table 1, Figure 1 and item 2.7 in AIP Norway).

2.13 Winter operations and friction measurements

The investigations into this incident support AIBN's earlier findings with respect to winter operations and friction measurements, which indicate that there is no basis for safe landing calculations when using today's basis for calculations.

2.14 Human factors

2.14.1 This incident, just like earlier accidents and incidents related to slippery runways, confirms that the Norwegian winter concept is complicated to work with for the people involved, including air pilots, air traffic controllers and the airport personnel.

2.14.2 The regulations for runway treatment are founded on the ICAO recommendations, which are in turn founded on vaguely substantiated scientific data. The regulations are formulated in a way that require extensive knowledge of physics and meteorology, as well as experience in evaluating the friction conditions on contaminated surfaces. It is the opinion of the AIBN that it is not realistic to expect the involved personnel to be able to perform these duties in a proper and sound manner based on today's regulations.

2.14.3 The pilot's procedures, which in this case relate to Airbus' airplanes, are based on EASA's and Airbus' assumptions that certain types of contaminations result in specific friction characteristics. AIBN's many investigations indicate there are no such clear physical correlations that an airplane's landing distance can be reliably calculated using such "presumed" friction values. AIBN feels that the regulations can place the pilots in-command in a difficult position due to the general "production pressure".

2.14.4 The air traffic controllers do their utmost to keep air traffic flowing. It is understandable that they evaluate the traffic picture and try to coordinate runway treatment to periods with gaps in the air traffic.

2.14.5 In the airport organisation the responsibility of deciding to close the runway for treatment has been allocated to the Airport Supervisor. AIBN feels that this puts a substantial and heavy responsibility on the Airport Supervisor. It seems natural that this person would like to confer with the air traffic controllers before deciding to close the runway for treatment. This might mean that closing is postponed for as long as possible. At the same time, the Airport Supervisor's basis for making a decision is complex and difficult to relate to.

2.14.6 It is AIBN's experience from such investigations that in hindsight it is often possible to point out where the involved personnel could have made a different decision and thereby prevented the incident. In an incident there are always several causal factors which either individually, or in combination, could have prevented the incident if avoided. Many of these factors are controlled by the involved pilots, air traffic controllers and airport personnel. In order for the personnel to achieve optimal interaction in the air transport system, the framework must be in place in the form of a set of regulations that is manageable in practice. Secondly; the pilots, air traffic controllers and airport personnel must be given the required training. AIBN considers that this incident shows that there is a clear potential for improvement with respect to evaluating landing conditions on contaminated runways both on the part of the airlines, the air traffic service, airport organisations, and in the national and international regulations.

2.14.7 In connection with investigations in the aftermath of accidents and incidents it is quite the norm to focus on human errors. It is the opinion of the AIBN that it is just as important to review which safety barriers that worked and the things that went well. In this case, the AIBN feels that the crew handled the emergency situation in a satisfactory manner and contributed to reducing the damage to the aircraft and injury to people. Likewise, the air traffic controller and the airport's fire and rescue service acted in a professional manner in this situation.

3. CONCLUSION

3.1 Investigation results

3.1.1 The aircraft

a) AIBN has found nothing to indicate that the airplane was not airworthy prior to the incident.

b) The aircraft's mass and balance were within the applicable limits.

c) The aircraft's fuel tanks contained approx. 3 400 kg JET A-1 fuel at the time of the incident.

3.1.2 The crew

a) The crew was certified and qualified for their mission.

b) The crew had taken off from Tenerife. The flight had been planned in accordance with the company's procedures based on the weather information available prior to their departure.

c) The crew obtained updated weather and runway status before their approach to ENTO. The landing was planned based on a dry runway with good Braking Action.

d) The first officer was PF until the deceleration of the aircraft after touchdown, when the commander took over the controls.

e) Three minutes before touchdown the crew were told that the runway was contaminated with 8 mm of wet snow and a braking action of 32-33-31 (MEDIUM). The crew made an assessment and decided that they were able to land with MEDIUM Braking Action.

f) Just before touchdown the aircraft came a little high on the glide slope. This entailed a long landing, and the aircraft set down approx. 787 m from the threshold on runway 18.

g) The aircraft landed with 140 KIAS from a V_{app} (VLS) of 147 KIAS. The speed was based on the correct V_{ref} for the actual landing mass and increased 5 kt for Auto Thrust and 5 kt for icing conditions. This is in line with the company's standard landing procedures but is not optimal on contaminated and slippery runways.

h) The aircraft was landed with a "soft" touch down in stead of "firm" as recommended.

i) The first officer did not sense any Braking Action. The commander suspected Auto Brake failure and tried to reset this. The first officer still did not feel any effect and engaged manual braking. This did not give any noticeable effect, and the commander took over the controls (PF).

j) The commander could not feel any Braking Action either, and therefore engaged the park brake (PB). At the same time he informed the TWR that they would skid off the runway.

k) The first officer informed the commander that the left-hand side of the runway was best suited for an excursion.

l) By using the PB rather than following the Airbus' procedure for brake failure, the commander was able to maintain nose wheel steering while at the same time getting alternative Braking Action from PB.

m) By engaging PB and attempting to turn to the left, the commander managed to get the aircraft to swerve which resulted in a sideways skidding action. This increased the friction and the aircraft came to a standstill at the very far end of the hard runway surface, as the nose wheel collided with an antenna base.

n) The commander evaluated the situation to be under control, and asked the passengers and crew to stay calm. He then requested assistance from the TWR to evacuate the passengers by means of aircraft stairs and busses. The passengers had to wait for about an hour before they could deplane and were transported to the terminal.

o) The cabin crew performed their safety duties inside the cabin in a satisfactory manner.

3.1.3 The weather conditions

a) Forecasts stated fairly good weather conditions, with snow expected for the afternoon. Based on the weather information the crew did not expect any weather or runway related problems.

b) Based on the received TAF, the crew expected to approach to runway 36. Before starting their approach to ENTO the crew received updated weather information and were also informed that they would use runway 18. They were also told that the runway was dry with good Braking Action.

c) The crew did not receive a SNOWTAM and were anticipating a dry runway as indicated in METAR and ATIS.

d) When checking in with TWR approx. 3 minutes before landing, the crew received information of a snow-contaminated runway, MEDIUM Braking Action and approx. 3 kt tailwinds. Even though this was the first time they were told of a contaminated runway, it did not give the crew cause for concern with regard to friction.

3.1.4 Survival aspects

a) The commander succeeded in stopping the aircraft on the last edge of the permanent runway surface. Only minor damage was inflicted on the aircraft and the commander decided that there was no need for an emergency evacuation of the aircraft.

b) The aircraft was evacuated via the front left cabin door in the usual manner by means of air stairs that had been driven out to the plane, and the passengers were transported to the terminal by bus. The crew stayed in the aircraft which was towed in at a later stage.

c) There were no personal injuries.

d) The fire and rescue service operated according to applicable plans and procedures.

3.1.5 The company's procedures

a) The company's procedures for winter operations were in line with the Airbus recommended procedures.

b) Airbus used the term *"fluid contaminated runways"* where specified quantities of dry snow, wet snow, slush, and water, were set as equivalents to wet runway. AIBN has established that Airbus' winter concept is unreliable.

3.1.6 Sandefjord Airport

a) Sandefjord Airport was late in initiating runway treatment. A contributory factor here was requests from ATC and another operator for possible landings and departures before the runway was closed. In this way the treatment of the runway kept being postponed until it was too late with regard to OY-VKA.

b) The decision was made to perform a friction measurement before the OY-VKA landed. Due to the limited time available, they only managed to carry out half a friction measurement (on one runway side).

c) The reports stated 8 mm of wet snow. The reporting intervals for wet snow were 6 mm. The 8 mm of wet snow should therefore have been reported as 12 mm wet snow. The measurement limitation for BV-11 was limited to 3 mm wet snow. AIBN finds that it does not matter much whether the report gave 8 mm or 12 mm of snow contaminant, or whether it was measured on 3 mm or 8 mm of wet snow. Regardless of the snow depth reported or the FC measured on wet snow, AIBN's investigations show that the attained ABC is in the order of 0.05 (POOR) on moist contamination.

d) The friction measurement and reported FC was of no importance with respect to the MyTravel (and Airbus) procedures. Airbus' landing data were mainly based on *"fluid contaminant"*. Appendix E shows that Airbus' procedures are based on the stated type of contamination, and secondarily on the FC reported.

e) The investigations have revealed that the winter operating procedures of Sandefjord Airport Torp were satisfactory, but that the personnel's knowledge of interpretation and application of the procedures were insufficient. AIBN still hold that this did not affect the outcome of this event, as several investigations have shown that there is limited correlation between internationally accepted procedures and experiences from Norwegian winter operations.

f) OY-VKA collided with a concrete basement which protruded above the runway surface. The basement was a safety hazard to aircraft and should not have been present.

3.1.7 Winter operations and friction measurements

a) The incident confirms AIBN's previous findings; that friction measurement on a moist contamination is highly uncertain and should be reported and responded to as UNRELIABLE or POOR.

b) The incident confirms that Boeing's concept of setting ABC at 0.20 for GOOD, 0.10 for MEDIUM and 0.05 for POOR, correlated with ICAO SNOWTAM values of 0.40, 0.30, and 0.20, is the safest method for calculating an airplane's braking distance when landing on a contaminated runway.

c) The incident confirms AIBN's previous findings that the Airbus concept of *"fluid contaminant"* did not provide a sufficiently safe classification of the friction characteristics when landing on a contaminated runway.

3.2 Significant investigation results

a) When landing on ENTO runway 18 with a reported FC 32-33-31 (MEDIUM) the crew experienced POOR Braking Action, and as a result the crew was unable to stop the aircraft in the normal manner. By means of an alternative braking and steering technique, the commander was able to bring the aircraft to a stop at the very far end of the hard runway surface.

When landing on a contaminated runway with a reported 8mm wet snow and a reported BA MEDIUM, the aircraft's effective braking coefficient (ABC) was in the order of 0.05. This is in line with Boeing's defined ABC for POOR.

4. SAFETY RECOMMENDATIONS

The Accident Investigation Board of Norway does not propose any safety recommendations with regard to general winter operations and friction measurements in this report. AIBN refers to the four previously published immediate safety recommendations (SL 06/1350-1, -2, -3, -4, cf. item 1.18.1.1) which are related to the ongoing theme investigation "*Vinteroperasjoner og friksjonsmålinger"* (Winter Operations and Friction Measurements).

In this investigation the AIBN issues three safety recommendations to MyTravel Scandinavia's (now Thomas Cook Airlines Scandinavia) and two safety recommendations to Sandefjord Airport Torp, related to operations on contaminated runways.

The Accident Investigation Board of Norway issues the following safety recommendations[4]:

Safety recommendation SL no. 2010/04T

Upon touchdown on runway contaminated by 8 mm new snow, with an air temperature of -2 °C and dewpoint temperature of -3 °C, the crew experienced very POOR Braking Action, whereas the reported was MEDIUM. AIBN recommends that MyTravel Airways Scandinavia/Thomas Cook Airlines Scandinavia evaluate if the procedures for use of the Airbus' concept of *"fluid contaminant"* allow the required safety margins when calculating landing distances on contaminated runways.

Safety recommendation SL no. 2010/05T

AIBN's investigations show there is poor (POOR) Braking Action on runways covered with moist contamination (loose, dry snow and new snow, slush) and a dewpoint spread of less than 3 K. AIBN recommends that MyTravel Airways Scandinavia/Thomas Cook Airlines Scandinavia evaluete if the procedures for use of FC values for moist contaminations.allow the required safety margins.

Safety recommandation SL no. 2010/06T

During landing on contaminated/slippery runway OY-VKA was landed longer in on the runway due to deviation from optimal procedures for such conditions. Further, there were indications on crew uncertainties regarding correct functioning of the Auto Brake system. AIBN recommends that MyTrave Airways Scandinavia/Thomas Cook Airlines Scandinavia uses this incident in their training of their pilots in winter operations.

Safety recommendation SL no. 2010/07T

AIBN has found that Sandefjord Airport Torp had well prepared winter maintenance procedures but that there were uncertainties regarding the correct application of the procedures. AIBN recommends that Sandefjord Airport Torp uses this incident as an example in their training of their personnel in winter operations.

Safety recommendation SL no. 2010/08T

During landing on a slippery runway OY-VKA collided with a Localizer Monitoring Antennae basement which protruded above the runway surface. AIBN recommends that Sandefjord Airport Torp perform a risk assessment regarding the safety zones adjacent to the runway.

Accident Investigation Board of Norway

Lillestrøm, 9. March 2010

[4] The Ministry of Transport and Communications ensures that safety recommendations are presented to the aviation authority and/or other involved ministries for consideration and processing, cf. Section 17 of the Regulation relating to public investigations of aviation accidents and aviation incidents in civil aviation.

REFERENCES

1. AIBN RAP 2009/07, LN-BRV.

   http://www.aibn.no/luftfart/rapporter/2009-07

2. AIBN RAP 2009/06, LN-WIR.

   http://www.aibn.no/luftfart/rapporter/2009-06

3. AIBN RAP 2007/25, G-CRPH.

   http://www.aibn.no/luftfart/rapporter/2007-25

4. AIBN RAP 2002/23, LN-WIL

   http://www.aibn.no/luftfart/rapporter/2002-23

5. James Reason. Managing the Risks of Organizational Accidents. Ashgate 1997.
6. Sidney Dekker. The Field Guide to Understanding Human Error. Ashgate 2006.
7. Sidney Dekker. Just Culture, Balancing Safety and Accountability. Ashgate 2007.

APPENDICES

APPENDIX A

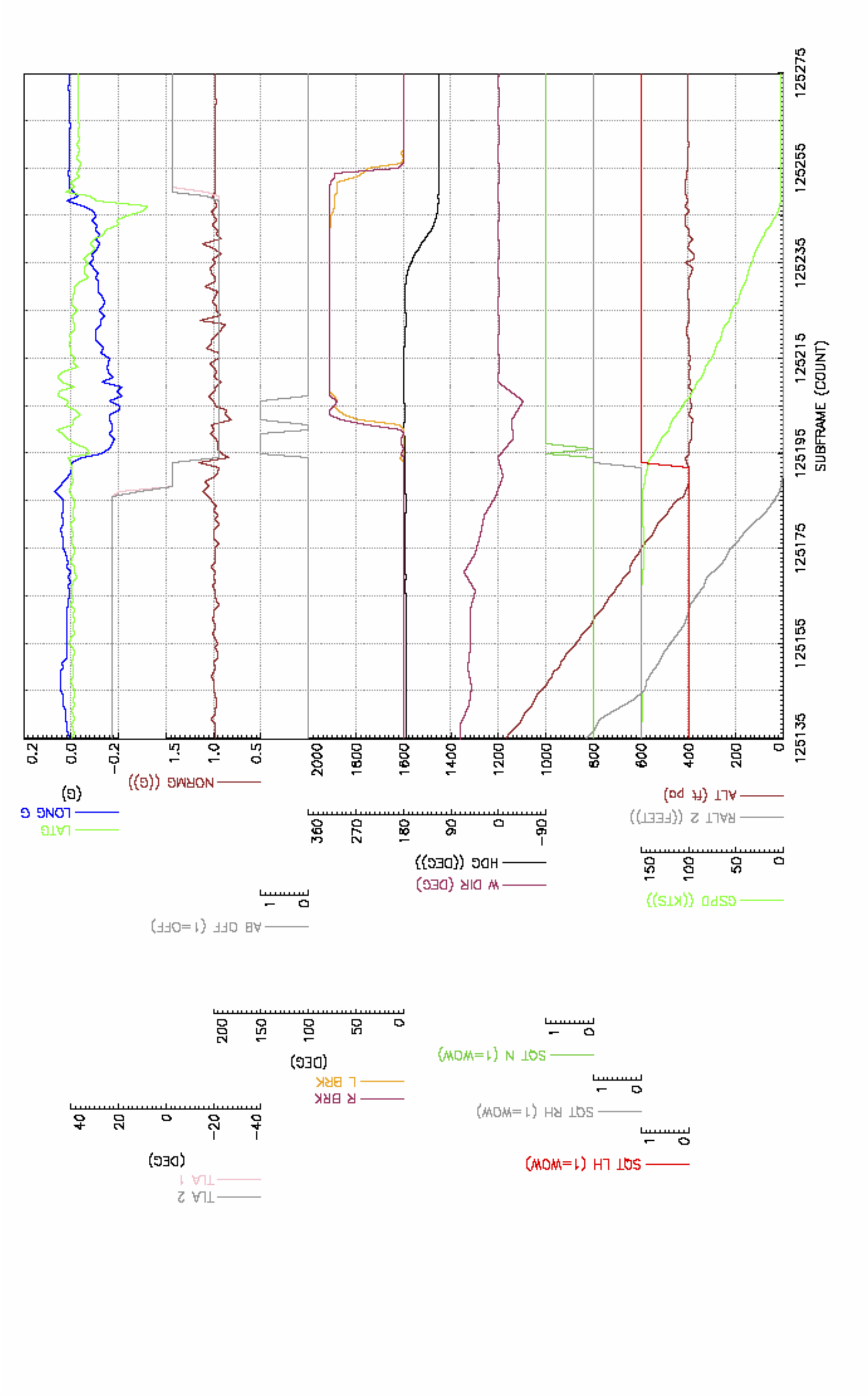
ABBREVIATIONS

AB	Autobrake
ABC	Airplane Braking Coefficient (Effective μ)
AIBN	Accident Investigation Board Norway
APU	Auxiliary Power Unit
AT	Auto Trottle
ATIS	Air Traffic Information Services
ATPL	Air Transport Pilot Licence
BA	Braking Action
CAP	Civil Aviation Procedures (UK)
CPC	Cockpit Performance Computer
CPL	Commercial Pilot Licence
CRFI	Canadian Runway Friction Index
EASA	European Aviation Safety Agency
ENTO	Sandefjord Airport Torp
FAA	Federal Aviation Administration
FC	Friction Coefficient
FCOM	Flight Crew Operations Manual
FMGC	Flight Management and Guidance Computer
GCTS	Tenerife Airport
GMC	Gross Mass Chart
GS	Ground Speed
ICAO	International Civil Aviation Organisation
ILS	Instrument Landing System
JAR-FCL	Joint Aviation Regulation – Flight Crew Licence
KIAS	Knots Indicated Air Speed

LDA	Landing Distance Available
LDR	Landing Distance Required
LFV	Luftfartsvæsen (Aviation Authority)
LTT	Lufttrafikktjenesten (Air Traffic Services)
METAR	Meteorological Aerodrome Report
NDB	Non Directional Beacon
NM	Nautical Miles
NOTAM	Notice To Airmen
NPH	Nominal Post Holder
OPC	Operational Proficiency Check
PF	Pilot Flying
PM	Performance Manual
PNF	Pilot Not Flying
QRH	Quick Reference Handbook
RH	Radio Height
SAFO	Safety Alert for Operators
AIBN	Accident Investigation Board of Norway
SKH	Skiddometer (high pressure tyre)
SFH	Surface Friction Tester (high pressure tyre)
SMS	Safety Management System
SNOWTAM	SNOWnotice To Airmen
TAF	Terminal Aerodrome Forecast
TWR	Tower Control
UTC	Universal Time Coordinated
VOR	VHF Omnidirectional Ranging
VLS	Landing Speed

APPENDIX B

FDR DATA



APPENDIX C

SUBJECT: Landing Distance Calculation for A321 at TRF

This memo will address the issue of RWY Conditions and Landing Distance Calculations related to the A321 Incident at ENTO 26/3 2006. A Landing Mass of 72 t has been used in these calculations.

RWY Conditions.

According to the initial reporting, the RWY was covered by 8 mm Wet Snow, and the Barking Action was measured to between 30 and 35 all along the Runway.

According to the Airbus FCOM and the MyTravel Performance Manual the Landing Distance Calculations for these conditions should be made for ¼ inch (6.3 mm) of Slush.

Note! 8 mm Wet Snow is equivalent to 4 mm of Slush, whish is more than what is considered equivalent to Wet.

Landing Distance.

The basic calculations made available from Airbus are assuming that the approach is flown with a Vref of 1.23 x Vs1g, and the use of Maximum Braking at Touch Down. The calculations can be made with or without the use of reversers.

Note! The use of Autobrake in Medium will on a slippery runway have the same effect as Max Braking, except for the small delay on activation after Touch Down.

According to the initial reporting, the landing was performed in a slight Tailwind, and with additional speed on top of Vref. The speed had been increased due to Auto-Thrust active (+5 kt) and suspected Icing on unheated surfaces (+5 kt).

Corrections for these conditions are available, so that the Actual Landing Distance for all of the above conditions can be made.

Calculation Summery.

The Landing Distance Available (LDA) at ENTO (both RWY´s) is 2569 metres.

The calculations are made assuming Maximum Braking and the use of Full Reverse.

The below calculations indicates that the LDA at ENTO was sufficient to cover both the Actual Landing Distance and the Required LDA (+15%).

Actual Landing Distance			
Speed/Wind	**0**	**TW 5**	**TW 10**
Vref	< 1600 m	< 1800 m	< 1900 m
Vref + 10	< 1800 m	< 2000 m	< 2200 m

Required LDA (+15%)			
Speed/Wind	**0**	**TW 5**	**TW 10**
Vref	< 1800 m	< 2000 m	< 2200 m
Vref + 10	< 2100 m	< 2300 m	< 2500 m

Note! The above figures are approximate.

Detailed Calculations.

The Calculations have been made parallel, using the 3 different methods available:

- Pre-calculated Gross Mass Charts from the Performance Manual.
- FCOM Calculations (Also published in Performance Manual)
- Airbus PEP (Performance Engineering Prandrams) – not available to the pilots.

All methods showed consistency, giving almost the same results.

Gross Mass Chart:

The Gross Mass Chart indicates that for the given conditions, the Maximum Landing Mass was 96,228 kg for 5 kt. TW and 88,615 kg for 10 kt. TW. These masses however, are assuming an approach speed of Vref, and not the slightly higher speed actually flown.

These data are correct when checked by the PEP prandram.

With a 10 kt increase in Approach Speed, the Maximum Landing Mass will decrease by approximately 8–10,000 kg. (Calculated by PEP)

FCOM Calculations:

The calculations made from the Landing Distance Table on FCOM 2.03.10 page 3 gives an Actual Landing distance on 6.3 mm slush of ***1550 m.*** (with full reverse)

Corrected for 5 kt of Tailwind and 10 kt of additional speed this gives approx ***1995 m***.

This means a required LDA of ***2295m***. (+15%)

PEP Calculations:

The PEP Calculations are confirming the other types of calculations available to the pilots.

Note! The PEP Calculations are the certified data, and if desired detailed calculations with any combination of wind, speed and reversers are available from this source.

Operations Engineering
MyTravel Airways A/S

APPENDIX D-1

A319/A320/A321 MY TRAVEL FLIGHT CREW OPERATING MANUAL	SPECIAL OPERATIONS	2.04.10	P 1
	FLUID CONTAMINATED RUNWAY	SEQ 001	REV 32

GENERAL

This section presents the recommendations of Airbus Industrie for operations from wet runways or from runways which are covered with contaminants such as standing water, slush or snow.

CAUTION
Take off from an icy runway is not recommended.

DEFINITIONS

DAMP : A runway is damp when the surface is not dry, but when the water on it does not give it a shiny appearance.

WET : A runway is considered as wet when the surface has a shiny appearance due to a thin layer of water. When this layer does not exceed 3 mm depth, there is no substantial risk of hydroplaning.

STANDING WATER : is caused by heavy rainfall and /or insufficient runway drainage with a depth of more than 3 mm.

SLUSH : is water saturated with snow which spatters when stepping firmly on it. It is encountered at temperatures around 5° C and its density is approximately 0.85 kg/liter (7.1 lb/US GAL).

WET SNOW : is a condition where, if compacted by hand, snow will stick together and tend to form a snowball. Its density is approximately 0.4 kg/liter (3.35 lb/US GAL).

DRY SNOW : is a condition where snow can be blown if loose, or if compacted by hand, will fall apart again upon release. Its density is approximately 0.2 kg/liter (1.7 lb/US GAL).

COMPACTED SNOW : is a condition where snow has been compressed (a typical friction coefficient is 0.2).

ICY : is a condition where the friction coefficient is 0.05 or below.

The performance given in this chapter has been divided into two categories which are determined by the depth of the contaminant. For each of these categories an equivalent depth of contaminant has been defined for which the performance deterioration is the same.

1. WET RUNWAY and EQUIVALENT

   Equivalent of a wet runway is a runway covered with or less than :
   - 2 mm (0.08 inch) slush
   - R 3 mm (0.12 inch) water
   - 4 mm (0.16 inch) wet snow
   - 15 mm (0.59 inch) dry snow

VKG ALL

APPENDIX D-2

A319/A320/A321 MYTRAVEL FLIGHT CREW OPERATING MANUAL	SPECIAL OPERATIONS	2.04.10	P 2
	FLUID CONTAMINATED RUNWAY	SEQ 001	REV 37

2. CONTAMINATED RUNWAY

R An equivalence between depth of slush and snow has been defined :
- 12.7 mm (1/2 inch) wet snow is equivalent to 6.3 mm (1/4 inch) slush
- R 25.4 mm (1 inch) wet snow is equivalent to 12.7 mm (1/2 inch) slush
- 50.8 mm (2 inches) dry snow is equivalent to 6.3 mm (1/4 inch) slush
- R 101.6 mm (4 inches) dry snow is equivalent to 12.7 mm (1/2 inch) slush

Note : 1. On a damp runway no performance degradation should be considered.
2. It is not recommended to take off from a runway covered with more than 4 inches of dry snow or 1 inch of wet snow.

OPERATIONAL CONDITIONS

Performance penalties for takeoff as published in this section are computed with the following assumptions :
- The contaminant is in a layer of uniform depth and density over the entire length of the runway.
- Antiskid and spoilers are operative.
- The friction coefficient is based on studies and checked by actual tests.
- The screen height at the end of takeoff segment is 15 feet, not 35 feet.

In addition, for contaminated runways only :
- There is drag due to rolling resistance of the wheels.
- There is drag due to spray on the airframe and gears.
- Reverse thrust is used for the deceleration phase.
- Maximum thrust is used for takeoff.

Note : The net flight path clears obstacles by 15 feet instead of 35 feet.

VKG ALL

APPENDIX E-1

MyTravel	**TRF/ENTO/18**	**CONF 2 CONT**
A321-211/CFM56-5B3	SANDEFJORD /TORP	QNH 1013 hPa
		Packs: OFF
AD Elev 286 ft Slope -0,29%	RWY-width 45 m	Anti Ice: OFF
TORA 2839 m TODA 2989 m	ASDA 2839 m LDA 2569 m	Thrust Reverser: Operational

Takeoff - Standing Water 6mm

OAT	TW 5	0 (Calm)	HW 10	HW 20
0° C	87812 (68) O [C2] 131/148/150	90492 (66) O [C2] 137/150/152	92320 (68) O [C2] 142/152/153	93802 (65) O [C2] 146/154/156
10° C	86655 (68) O [C2] 129/147/149	89340 (68) O [C2] 135/149/151	91162 (69) O [C2] 139/151/153	92875 (68) O [C2] 143/152/154
20° C	85395 (64) O [C2] 127/145/148	88111 (66) O [C2] 133/148/150	89876 (69) O [C2] 136/150/152	91705 (71) O [C2] 141/151/153
30° C	83888 (88) O [C2] 125/144/147	86668 (90) O [C2] 130/147/149	88444 (90) O [C2] 134/149/151	90229 (88) O [C2] 138/150/152

Takeoff - Standing Water 12mm

OAT	TW 5	0 (Calm)	HW 10	HW 20
0° C	85964 (51) O [C2] 134/147/149	88812 (68) O [C2] 139/149/151	90744 (72) O [C2] 143/151/152	92703 (73) O [C2] 147/153/154
10° C	84618 (67) O [C2] 131/145/148	87626 (69) O [C2] 137/148/150	89457 (71) O [C2] 141/150/151	91435 (73) O [C2] 145/152/153
20° C	83294 (65) O [C2] 129/144/146	86260 (65) O [C2] 135/147/149	88135 (68) O [C2] 139/149/150	90021 (69) O [C2] 142/151/152
30° C	81810 (87) O [C2] 127/143/145	84782 (88) O [C2] 133/146/148	86627 (91) O [C2] 137/148/149	88492 (95) O [C2] 140/149/151

Corrections:	6mm	12mm
FLAPS	C2	C2
PACKS ON	-1780	-1708
Eng A/I ON	-277	-255
Eng + Wing A/I ON	-913	-843

Takeoff - Slush 6mm

OAT	TW 5	0 (Calm)	HW 10	HW 20
-5° C	88497 (67) O [C2] 133/148/151	91243 (68) O [C2] 140/151/153	92931 (84) C [C2] 144/152/154	94324 (66) O [C2] 148/156/157
0° C	87916 (66) O [C2] 132/148/150	90648 (72) O [C2] 138/150/152	92390 (75) O [C2] 143/152/153	93866 (65) O [C2] 147/155/156
5° C	87336 (66) O [C2] 131/147/150	90061 (67) O [C2] 137/150/152	91830 (68) O [C2] 141/151/153	93405 (65) O [C2] 145/154/155
10° C	86741 (66) O [C2] 130/147/149	89470 (71) O [C2] 136/149/152	91278 (71) O [C2] 140/151/153	92936 (68) O [C2] 144/153/154
15° C	86096 (67) O [C2] 129/146/149	88842 (66) O [C2] 135/149/151	90644 (73) O [C2] 139/150/152	92371 (75) O [C2] 143/152/153

Takeoff - Slush 12mm

OAT	TW 5	0 (Calm)	HW 10	HW 20
-5° C	86401 (69) O [C2] 136/147/149	89330 (72) O [C2] 142/150/151	91318 (71) O [C2] 145/152/153	93190 (66) O [C2] 149/154/154
0° C	85730 (67) O [C2] 135/147/148	88698 (65) O [C2] 140/150/151	90683 (72) O [C2] 144/151/152	92634 (73) O [C2] 148/153/154
5° C	85069 (64) O [C2] 134/146/148	88077 (65) O [C2] 139/149/150	90031 (71) O [C2] 143/151/152	91988 (77) O [C2] 147/153/153
10° C	84426 (64) O [C2] 133/146/147	87443 (68) O [C2] 138/149/150	89371 (75) O [C2] 142/150/151	91328 (74) O [C2] 146/152/153
15° C	83758 (67) O [C2] 132/145/147	86773 (68) O [C2] 137/148/149	88684 (70) O [C2] 141/150/151	90638 (72) O [C2] 144/152/152

Corrections:	6mm	12mm
FLAPS	C2	C2
PACKS ON	-1760	-1730
Eng A/I ON	-277	-267
Eng + Wing A/I ON	-913	-893

Limit code: B=Brake, C=Climb, F=Field, O=Obstacle, P=T/O Thrust, R=V2 restriction, S=Structural, T=Tire and V=Vmc

Max acceleration height: 1940 ft
Min acceleration height: 800 ft

Obstacles included in calculation (from end of RWY)
Obst distance (m) 170
Obst height (ft) 43

Eng Fail: Climb on 179°. At 1800 turn left to TOR HP. D113.85 TOR HP:Inbound 360°, right turn.

15%MARGIN (LDA = 1.15 * LDR) — **Landing - Standing Water 6mm (Conf FULL)** — **ADVISORY INFORMATION**

TW 10	TW 5	0 (Calm)	HW 10	HW 20	HW 30
79782	86968	94450	99102	100000	100000

15%MARGIN (LDA = 1.15 * LDR) — **Landing - Standing Water 12mm (Conf FULL)** — **ADVISORY INFORMATION**

TW 10	TW 5	0 (Calm)	HW 10	HW 20	HW 30
84108	90990	98231	100000	100000	100000

15%MARGIN (LDA = 1.15 * LDR) — **Landing - Slush 6mm (Conf FULL)** — **ADVISORY INFORMATION**

TW 10	TW 5	0 (Calm)	HW 10	HW 20	HW 30
88637	96253	100000	100000	100000	100000

15%MARGIN (LDA = 1.15 * LDR) — **Landing - Slush 12mm (Conf FULL)** — **ADVISORY INFORMATION**

TW 10	TW 5	0 (Calm)	HW 10	HW 20	HW 30
92564	100000	100000	100000	100000	100000

DATE: April 19, 2006 — EAG ToDc A321-211 Version 1.3.2 / ObstData 060419 / Dataset AC211B05 JAR / OCTOPUS 23.1.1

APPENDIX E-2

MyTravel	**TRF/ENTO/18**	**CONF 2 SLIP**
A321-211/CFM56-5B3	SANDEFJORD /TORP	QNH 1013 hPa
		Packs: OFF
AD Elev 286 ft Slope -0,29%	RWY-width 45 m	Anti Ice: OFF
TORA 2839 m TODA 2989 m	ASDA 2839 m LDA 2569 m	Thrust Reverser: Operational

Takeoff - Slippery FC = 40 (Good)

OAT	TW 5	0 (Calm)	HW 10	HW 20
-20° C	93242 (59) O [C2] 145/152/155	95141 (62) O [C2] 150/157/159	96298 (63) O [C2] 154/160/162	97420 (63) O [C2] 158/164/165
-15° C	92844 (63) O [C2] 144/151/154	94806 (62) O [C2] 149/156/158	95991 (63) O [C2] 153/159/161	97117 (63) O [C2] 155/163/164
-10° C	92410 (63) O [C2] 144/151/153	94434 (62) O [C2] 149/155/157	95621 (62) O [C2] 152/158/160	96738 (64) O [C2] 154/162/163
-5° C	91987 (63) O [C2] 142/150/153	94028 (62) O [C2] 148/154/156	95261 (62) O [C2] 151/157/159	96402 (64) O [C2] 153/161/163
0° C	91583 (61) O [C2] 141/150/153	93612 (62) O [C2] 147/153/156	94887 (62) O [C2] 150/157/159	96044 (63) O [C2] 152/160/162
5° C	91173 (62) O [C2] 140/150/153	93197 (64) O [C2] 146/152/155	94480 (62) O [C2] 149/156/158	95675 (63) O [C2] 151/159/161

Takeoff - Slippery FC = 34 (Med - Good)

OAT	TW 5	0 (Calm)	HW 10	HW 20
-20° C	92419 (67) O [C2] 140/151/154	94546 (66) O [C2] 146/156/158	95984 (65) O [C2] 151/159/161	97186 (66) O [C2] 155/163/165
-15° C	91994 (68) O [C2] 139/150/153	94205 (65) O [C2] 145/155/157	95607 (66) C [C2] 149/158/160	96829 (66) O [C2] 153/162/164
-10° C	91504 (72) O [C2] 137/150/153	93755 (70) O [C2] 144/154/156	95156 (57) O [C2] 148/157/159	96430 (61) O [C2] 152/161/162
-5° C	91023 (62) O [C2] 136/150/153	93302 (65) O [C2] 142/153/155	94727 (66) O [C2] 146/156/158	96020 (53) O [C2] 151/160/161
0° C	90533 (67) O [C2] 135/149/152	92839 (69) O [C2] 141/151/154	94269 (66) O [C2] 145/155/157	95610 (66) O [C2] 149/159/160
5° C	90029 (67) O [C2] 134/149/152	92381 (69) O [C2] 140/151/153	93816 (65) O [C2] 144/154/156	95197 (66) O [C2] 148/158/159

Corrections:	FC = 40	FC = 34
FLAPS	C2	C2
PACKS ON	-2096	-1862
Eng A/I ON	-343	-277
Eng + Wing A/I ON	-1160	-926

Takeoff - Slippery FC = 26 (Medium)

OAT	TW 5	0 (Calm)	HW 10	HW 20
-20° C	90194 (66) O [C2] 126/149/152	92614 (67) O [C2] 133/151/154	94142 (65) O [C2] 138/155/157	95607 (65) O [C2] 143/158/160
-15° C	89689 (67) O [C2] 125/148/152	92196 (68) O [C2] 132/150/153	93722 (64) O [C2] 137/154/156	95188 (66) O [C2] 141/157/159
-10° C	88696 (91) F [C2] 124/148/151	91702 (68) O [C2] 131/150/153	93255 (64) O [C2] 135/152/155	94729 (66) O [C2] 140/156/158
-5° C	87485 (88) F [C2] 123/147/150	91212 (69) O [C2] 129/150/153	92740 (80) O [C2] 134/151/154	94274 (66) O [C2] 139/155/157
0° C	86310 (79) F [C2] 122/145/149	90700 (67) O [C2] 128/149/152	92328 (69) O [C2] 133/151/153	93819 (68) O [C2] 137/154/156
5° C	85176 (80) F [C2] 121/144/148	90180 (73) O [C2] 127/149/152	91826 (75) O [C2] 132/150/153	93348 (65) O [C2] 136/153/155

Takeoff - Slippery FC = 16 (Poor)

OAT	TW 5	0 (Calm)	HW 10	HW 20
-20° C	59012 (76) F [C2] 113/120/129	77065 (78) F [C2] 114/136/141	82613 (93) F [C2] 118/142/146	87937 (85) F [C2] 123/147/150
-15° C	56601 (72) F [C2] 113/120/129	75793 (79) F [C2] 113/135/140	81296 (81) F [C2] 117/140/145	86600 (71) F [C2] 122/146/149
-10° C	54340 (58) F [C2] 113/120/129	74213 (117) F [C2] 112/133/139	80006 (77) F [C2] 116/139/144	85315 (76) F [C2] 121/144/148
-5° C	52253 (49) F [C2] 113/120/129	70758 (106) F [C2] 112/130/136	78762 (79) F [C2] 115/138/143	84066 (79) F [C2] 120/143/147
0° C	50297 (58) F [C2] 114/120/129	67782 (90) F [C2] 112/127/133	77530 (76) F [C2] 115/137/142	82836 (92) F [C2] 119/142/146
5° C	48451 (61) F [C2] 114/120/130	65048 (86) F [C2] 112/124/131	76317 (75) F [C2] 114/136/141	81577 (91) F [C2] 118/141/145

Corrections:	FC = 26	FC = 16
FLAPS	C2	C2
PACKS ON	-1840	-427
Eng A/I ON	-275	-158
Eng + Wing A/I ON	-939	-210

Limit code: B=Brake, C=Climb, F=Field, O=Obstacle, P=T/O Thrust, R=V2 restriction, S=Structural, T=Tire and V=Vmc

Max acceleration height: 1890 ft
Min acceleration height: 800 ft

Obstacles included in calculation (from end of RWY)
Obst distance (m) 170
Obst height (ft) 43

Eng Fail: Climb on 179°. At 1800 turn left to TOR HP. D113.85 TOR HP:Inbound 360°, right turn.

15%MARGIN (LDA = 1.15 * LDR)

Landing - Slippery

ADVISORY INFORMATION

Landing (Reported FC):			40	35	30	25	20
CONF FULL		5kt TW	100000	100000	92118	79024	66779
CONF FULL		Calm	100000	100000	100000	87077	74814
CONF FULL		5kt HW	100000	100000	100000	89912	77549
CONF 3	1 REV INOP	5kt TW	100000	89568	76251	63740	51987
CONF 3	1 REV INOP	Calm	100000	97895	84345	71071	59313
CONF 3	1 REV INOP	5kt HW	100000	100000	86871	73807	61830

DATE: April 19, 2006

EAG ToDc A321-211 Version 1.3.2 / ObstData 060419 / Dataset AC211B05 JAR / OCTOPUS 23.1.1

APPENDIX F

A319/A320/A321 MY TRAVEL	IN FLIGHT PERFORMANCE	REV 36 / SEQ 280	4.03

LANDING DISTANCE WITHOUT AUTOBRAKE

The actual landing distance is the distance to come to a complete stop from a point 50 ft above the landing surface. No margin is included in this distance.

CONFIGURATION FULL

ACTUAL LANDING DISTANCE (METERS)												
WEIGHT (1000 KG)			58	62	66	70	74	78	82	86	90	94
RUNWAY CONDITION	DRY		820	850	890	920	960	1010	1080	1280	1370	1460
	WET		1040	1100	1170	1230	1300	1360	1430	1540	1630	1710
	COVERED WITH	6.3 MM (1/4INCH) WATER	1460	1560	1660	1760	1860	1970	2060	2170	2270	2370
		12.7 MM (1/2INCH) WATER	1400	1500	1590	1690	1780	1870	1960	2050	2150	2240
		6.3 MM (1/4INCH) SLUSH	1420	1500	1580	1670	1760	1850	1940	2030	2130	2210
		12.7 MM (1/2INCH) SLUSH	1370	1450	1530	1610	1690	1780	1860	1950	2050	2130
		COMPACTED SNOW	1330	1400	1460	1530	1590	1640	1700	1760	1820	1870
		ICE	2790	2910	3030	3160	3280	3390	3510	3630	3750	3860

CORRECTIONS

	CORRECTION ON ACTUAL LANDING DISTANCE							
	dry runway	wet runway	runway covered with					
			1/4 inch water	1/2 inch water	1/4 inch slush	1/2 inch slush	compacted snow	ice
per 1000 ft above SL	+ 3 %	+ 4 %	+ 4 %	+ 4 %	+ 5 %	+ 4 %	+ 3 %	+ 4 %
per 10 kt headwind	No correction for headwind due to wind correction on approach speed							
per 10 kt tailwind	+ 17 %	+ 22 %	+ 24 %	+ 22 %	+ 22 %	+ 20 %	+ 16 %	+ 27 %
2 reversers operative	-4 %	-7 %	-11 %	-10 %	-11 %	-10 %	-8 %	-21 %
Per 5 kt speed increment (and no failure) add 8% (all runways)								

NOTE : – THE ABOVE DISTANCES ARE GIVEN FOR USE IN FLIGHT
– BEFORE DEPARTURE REFER TO FCOM

APPENDIX G

Friction measurements and uncertainties

The Accident Investigation Board has been able to document that friction measurements from all the approved friction measurement devices/appliances suffer from uncertainty in the range of ± 0.10 under dry conditions and ± 0.20 under wet (moist) conditions. Please see Table 1.

YEAR	Organisation	Uncertainty	Remark
1962	ICAO	± 0.01	Reported by a State
1974	ICAO	± 0.15 - 0.20	Wet surfaces
1974	ICAO	± 0.10 - 0.15	Compacted snow and ice surfaces
1990	NASA	± 0.10	Aircraft/FC contaminated
2005	ASTM	± 0.05 - 0.20	Use of ASTM standard 2100-04

Table 1. Uncertainty of friction measurements of contaminated surfaces (Norheim, Avinor 2005).

AIBN's investigations also shown there to be moist conditions with dewpoint spread (the difference between air temperature and dewpoint) of < 3 K, even at frost degrees (when the temp. is below minus Celsius. This is illustrated in Figure 1 which shows a big difference in friction for compacted snow at temperatures above and below minus 15°C. Figure 1 is taken from Transport Canada and demonstrates some of the uncertainties that befall friction measurements on contaminated surfaces.

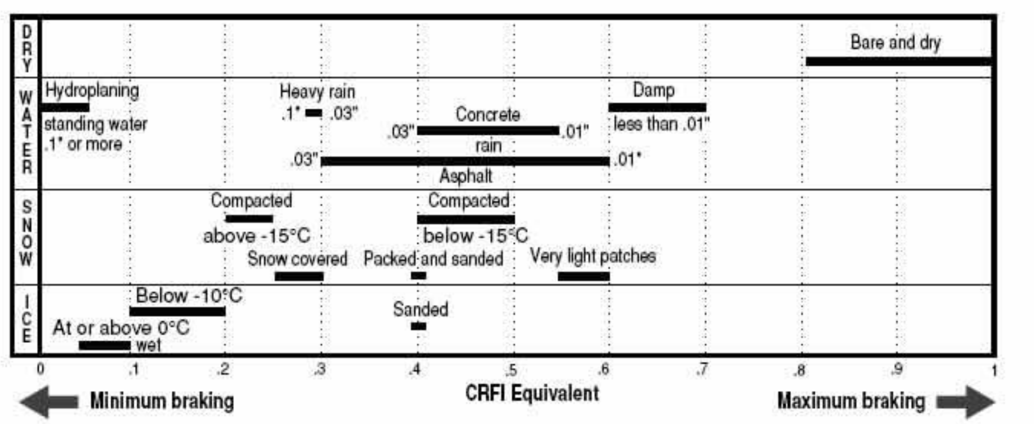


Figure 1. Uncertainty of friction measurements on contaminated surfaces (Transport Canada 2004)

APPENDIX H

Excerpt of Norwegian requirements for winter maintenance

Aeronautical Information Publication Norway (AIP Norway[5]), AIP Norway, AD 1.2, item 2.4 and 2.5 describes the Norwegian requirements for runway treatment and reporting.

Treatment and reporting

"2.4 Treatment

The surfaces of the movement area shall be treated so as to obtain the best friction possible, with special attention to the runway. To obtain better friction, mechanical treatment, chemicals and sand are used. Close cooperation between the aerodrome operator and the aircraft operators are compulsory in avoiding chemicals that can harm aircraft.

2.5 Reporting

2.5.1 The international SNOWTAM format is used for reporting the winter conditions at the movement area. The format is described in ICAO Annex 15, Appendix 2.

2.5.2 The conditions in the movement area shall be reported to the air traffic services by way of a runway report which will form the basis for the air traffic service's issue of a SNOWTAM.

Special attention must be made to the following:

G − Mean depth

The mean depth of the deposits of loose snow of slush reported under item F, is reported for each third of the runway as viewed from the threshold having the lower runway number. The depth is reported in millimetre to an accuracy of 20 mm for dry snow, 10 mm for wet snow and 3 mm for slush, and is rounded upwards, which means that wet snow between 10 and 20 mm is reported as 20 mm. If the depth of snow or is considered to be of no aviation operative effect, the letters XX can be reported. This requires that the aircraft operators have given the aerodrome operator the necessary background for the use of XX.

H – Friction level

The friction level on the runway can be reported as measured or estimated. If the aerodrome operator is unable to vouch for the friction level or the conditions outside the area covered by the friction measuring device, the figure 9 shall be reported. Measured friction level can only be reported when the conditions fall within the friction measuring device's area of application. The measured friction level is to be reported for each third of the runway seen from the threshold with the lowest runway number, and be reported with two digits (0 and decimal point to be omitted), followed by the abbreviation of the friction measuring device.

See items 2.6 and 2.7 below for further information. The friction level can be estimated by qualified personnel. The estimated friction level is reported for each

[5] AIP Norway rev 27 Oct. 2005

third of the runway seen from the threshold with the lowest runway number, and stated with 1 digit according to the following table:

5 Good Equivalent of friction level 0.40 and above

4 Medium good Equivalent of friction level 0.36 – 0.39

3 Medium Equivalent of friction level 0.30 – 0.35

2 Medium poor Equivalent of friction level 0.26 – 0.29

1 Poor Equivalent of friction level 0.25 and below

9 Cannot be estimated

<u>Norwegian definitions of snow types (BSL E 4-2 § 3. Definitions)</u>

"j) Snow (on the ground) :

1. *Dry snow: Snow which can be blown if loose or, if compacted by hand, will fall apart again upon release; specific gravity: below 0.35*
2. *Wet snow: Snow which, if compacted by hand, will stick together and tend to or form a snowball; specific gravity 0.35 or higher – but below 0.5.*
3. *Compacted snow: Snow which has been compacted into a solid mass that resists further compression and will hold together or break up into lumps if picked up; specific gravity: 0.5 and higher".*

<u>Friction measuring devices – area of application (AIP Norway, AD 1.2, item 2.6)</u>

2.6 Friction measuring devices and areas of application

2.6.1 The following friction measuring devices (tribometer) are approved for use on Norwegian airports:

– GRT Grip Tester

– SFH Surface Friction Tester, High pressure tyre

– SKH Skiddometer BV 11, High pressure tyre

– RUN Runar

– VIN Vertec Inspector

– TAP Tapleymeter

2.6.2 In general there is considerable uncertainty with regard to measurements conducted on a contaminated runway and especially in wet conditions – around zero degrees centigrade. The snow and ice is at its melting point.

TAP is, for example, not acceptable for use in wet conditions. See item 2.7 below for further information.

2.6.3 A measured friction level is associated with the friction measuring device that has been used, and cannot be taken as an independent value. The area of application for the different friction measuring devices are:

SKH/SFH:

– Dry snow up to 25 mm.

– Dry compact snow regardless of thickness

– Dry ice regardless of thickness

– Slush up to 3 mm.

– Wet snow up to 3 mm.

– Wet ice.

GRT/RUN/VIN:

– Dry snow up to 25 mm.

– Dry compact snow regardless of thickness

– Dry ice regardless of thickness

– Slush up to 3 mm.

– Wet snow up to 3 mm.

TAP:

– Dry snow up to 5 mm.

– Dry compact snow regardless of thickness

– Dry ice regardless of thickness.

<u>General uncertainty with use of measured friction values (AIP Norway, AD 1.2, item 2.7)</u>

2.7 SNOWTAM format item H

The table in item H, with descriptive caption, was developed in the early 1950s, based on data gathered on compact snow and ice only. The friction levels cannot be taken as absolute values, and are generally not valid for other surfaces than compact snow or ice. It is accepted, however, that friction level can be reported in conditions of up to 3 mm wet snow or slush, if a continuous friction measurement device is used. It is not possible to ascertain a numerical expression for the quality of the friction levels that are reported in SNOWTAM. Tests show that the accuracy indicated by the table cannot be achieved with present-day friction measuring devices. While the table has values measured into hundredths, tests show that only values stated in tenths, will be of operative value. The utmost caution must therefore be shown for the use of the reported friction levels, and use of the table must be based on the flight operator's own experience.

APPENDIX I

Excerpts of winter maintenance regulations for Sandefjord Airport Torp

Excerpts of "Winter maintenance for Sandefjord Airport Torp, winter season 2005/2006, aerodrome maintenance, Part C, Ch. 4.1”.

1. GENERAL

Flying in winter conditions is highly demanding for the operators. In the winter season the conditions with respect to weather and visibility are much more difficult than in the summer season, and the requirements concerning design and maintenance of the movement and safety areas are at least the same as in the summer.

Sandefjord Airport Torp (SLT) has an expressed ”Black runway philosophy”, which means that it is a priority for us to offer the companies a runway as free from snow and ice as at all possible. This objective also goes for taxiways and apron south.

Airport safety is of the highest priority, all assessments shall be made with safety in mind and to ensure that safety comes first at all times. Should conditions be of such a nature that there are doubts as to whether the airport safety can be maintained, the airport manager/operations manager shall be contacted and the runway/affected areas are to be closed for traffic.

For a braking action of below 0,30 (medium), the airport manager shall be contacted, and in case of further deterioration shall be kept continuously updated on developments. For a braking action of below 0.20 (poor), the affected areas are to be closed to traffic until satisfactory braking action has been re-established.

1.3 Winter maintenance comprises:

Inspections, BSL E 4-2 §6

Snow clearance, BSL E 4-2 §§8, 10, 12, 13

Treatment, BSL E 4-2 §8

Reporting, BSL E 4-2 §7

1.4 Scope

The winter maintenance shall be performed in such a manner and to such as scope that air traffic can be conducted in a safe and secure manner, cf. Section 8, BSL E 4-2. In addition, it should be an objective that air traffic is upheld to the largest possible extent.

----

2. RESPONSIBLE FOR SNOW CLEARANCE

The Airport Supervisor at Sandefjord Airport AS (SLAS) is responsible to ensure that winter maintenance is performed according to the applicable rules and regulations.

The Airport Supervisor SLAS reports to LTT Torp about 10 minutes before snow clearing is completed. Any delays shall be reported at once to LTT Torp and Widerøe to allow necessary air traffic-related priorities to be made.

The Airport Supervisor is not merely responsible, but obliged to close the runway to the extent that the requirements of BSL E 4-2 are not met with regard to:

- Critical snow banks/edges

- Events where a delay of runway treatment will result in a worsened situation and create much extra work (e.g. prolonged shut-down).

- Closing LZZ and GP for snow clearance shall take place upon agreement between the Airport Supervisor and the Air Traffic Controller, or when the Flight Navigation Engineer is present and reports in a requirement.

The SLAS Airport Supervisor is responsible to inspect the areas and ensure initiation of snow clearance in consultation with FNT before the depth of snow exceeds critical values. Cf. local instruction no. 1-2001 w/appendix.

----

3. CLOSING

The airport manager will, in consultation with the Airport Supervisor, or on his/her own initiative, close the whole or parts of the movement area under conditions that might pose a risk to the air traffic.

Runways and taxiways with ongoing snow clearing and treatment activities cannot be used by aircraft, and the areas cannot be reopened to traffic before they are again in compliance with the stipulated winter maintenance requirements.

3.1 Closing the area before the threshold

If the conditions on parts of the area in front of the threshold are considered not up to standard the whole area shall be closed. TORA/ASDA is announced for Reduced Take-Off Position, ref AIP Norway, ENTO AD 2.13.

3.2 When closing the runway

A temporary closing of the runway for winter maintenance activities is the responsibility of the SLAS Airport Supervisor.

The SLAS Airport Supervisor shall at once notify the air traffic controller and Widerøe shift leader on duty of the time and duration of the close-down.

The Airport Supervisor shall coordinate the time of closure of runway, taxiway with the on-duty air traffic controller and Widerøe shift leader as soon as possible. Traffic considerations shall be taken into account, but not to the extent that the requirements stipulated in BSL E 4-2 are not complied with.

Snow clearing/sweeping of the runway should be performed before peaks in traffic. In case of small or few aircraft, these must give way for larger groups.

Air ambulances etc. shall be prioritised.

4. SNOW CLEARANCE

Snow, slush and ice shall be removed from the runway as soon as possible.

----

8. BRAKING ACTION

An agreement has been made with the users of Sandefjord Airport Torp that the lowest brake figure is 35. For Braking Action lower than 35, the necessary improvement measures shall be initiated.

8.1 Braking measurement

Braking measurements are performed either with BV11, Vertec Inspector or Taplymeter and are performed by the Airport Supervisor or his deputy.

Braking Action measurements are to be performed twice a day as a minimum, and always when there is a change of conditions, or this is suspected, unless the friction coefficient can safely be evaluated to have a value of 0.60 (Braking Action – good) or better.

A runway report shall be submitted to LTT at least before the first flight takes place, and for change-over of shifts.

8.2 Conditions for braking measurements

When the runway report is to contain the measured friction level, the following preconditions must be present:

The runway must be ploughed until conditions come within the friction measuring device area of application.

If it is snowing, the whole runway must fall within the area of application before reopening, and it must not snow so hard that the level of friction has significantly changed.

Measured friction is difficult to report when wet snow or slush is falling. If use of the runway is permitted when the conditions are outside the friction measuring device area of application, a new runway report stating the depth of snow and friction level 9 be prepared at once.

The first measurement shall be conducted in the morning so that the result can be presented to LTT/TWR 20 minutes before airport opening time at the latest, and in addition, as soon as any change of braking action is detected or is presumed to have occurred and/or on request from TWR.

8.3 Sanding

The gritting lorry is parked in a heated garage and is manned by the Airport Supervisor. It shall be full and available at all times and be checked every day in the winter season. Runway treatment also applies for the clearway/stopway.

When sand is used on the runway this shall be applied so as not to cause damage to the aircraft.

APPENDIX J

EASA certification on contaminated runways

Excerpts of the EASA Certification Specifications for Large Aeroplanes CS-25 Book 2, Acceptable Means of Compliance:

"7.3 Braking Friction (All Contaminants)

On most contaminant surfaces the braking action of the aeroplane will be impaired. Performance data showing these effects can be based on either the minimum conservative 'default' values, given in Table 2 or test evidence and assumed values (see paragraph 7.3.2). In addition the applicant may optionally provide performance data as a function of aeroplane braking coefficient or wheel braking coefficient.

7.3.1 Default Values

To enable aeroplane performance to be calculated conservatively in the absence of any direct test evidence, default friction values as defined in Table 2 may be used. These friction values represent the effective braking coefficient of an anti-skid controlled braked wheel/tyre.

Contaminant	***Default Friction Value*** μ
Standing Water and Slush	$= -0.0632\left(\frac{V}{100}\right)^3 + 0.2683\left(\frac{V}{100}\right)^2 - 0.4321\left(\frac{V}{100}\right) + 0.3485$ where V is groundspeed in knots. Note: For V greater than the aquaplaning speed, use $\mu = 0.05$ constant
Wet Snow below 5mm depth	0.17
Wet Snow	0.17
Dry Snow below 10mm depth	0.17
Dry Snow	0.17
Compacted Snow	0.20
Ice	0.05

Note: Braking Force = load on braked wheel x Default Friction Value μ

Table 2

Note: For a specially prepared winter runway surface no default friction value can be given due to the diversity of conditions that will apply.

7.3.2 Other Than Default Values

In developing aeroplane braking performance using either test evidence or assumed friction values other than the default values provided in Table 2, a number of other brake related aspects should be considered. Brake efficiency *should be assumed to be appropriate to the brake and anti-skid system behaviour on the contaminant under consideration or a conservative assumption can be used. It can be assumed that wheel brake torque capability and brake energy characteristics are unaffected. Where the tyre wear state significantly affects the braking performance on the contaminated surface, it should be assumed that there is 20% of the permitted wear range remaining. Where limited test evidence is available for a model predecessor or derivative this may be used given appropriate conservative assumptions.*

7.3.3 Use of Ground Friction Measurement Devices

Ideally it would be preferable to relate aeroplane braking performance to a friction index measured by a ground friction device that would be reported as part of a Surface Condition Report. However, there is not, at present, a common friction index for all ground friction measuring devices. Hence it is not practicable at the present time to determine aeroplane performance on the basis of an internationally accepted friction index measured by ground friction devices. Notwithstanding this lack of a common index, the applicant may optionally choose to present take-off and landing performance data as a function of an aeroplane braking coefficient or wheel braking coefficient constant with ground speed for runways contaminated with wet snow, dry snow, compacted snow or ice.
The responsibility for relating this data to a friction index measured by a ground friction device will fall on the operator and the operating authority."

APPENDIX K

Airbus Industrie's policy for operations of contaminated runways

From Airbus Industrie's document "Getting to Grips with Cold Weather Operations", Airbus Industrie, Flight Operations Support, Customer Services Directorate, 1999, we quote:

"C3.4.2 Difficulties in assessing the effective μ

The two major problems introduced by the airport authorities' evaluation of the runway characteristics are:

-The correlation between test devices, even though some correlation charts have been established.

-The correlation between measurements made with test devices or friction measuring vehicles and aircraft performance.

-These measurements are made with a great variety of measuring vehicles, such as: Skiddometer, Saab Friction Tester (SFT), MU-Meter, James Brake Decelerometer (JDB),Tapley meter, Diagonal Braked Vehicle (DBV).

Refer to ICAO, Airport Services Manual, Part 2 for further information on these measuring vehicles.

The main difficulty in assessing the braking action on a contaminated runway is that it does not depend solely on runway surface adherence characteristics.

What must be found is the resulting loss of friction due to the interaction tire/runway.

Moreover, the resulting friction forces depend on the load, i.e. the aircraft weight, tire wear, tire pressure and anti-skid system efficiency.

In other words, to get a good assessment of the braking action of an A340 landing at 150,000 kg, 140 kt with tire pressure 240 PSI, the airport should use a similar spare A340... Quite difficult and pretty costly!

The only way out is to use some smaller vehicles. These vehicles operate at much lower speeds and weights than an aircraft. Then comes the problem of correlating the figures obtained from these measuring vehicles and the actual braking performance of an aircraft. The adopted method was to conduct some tests with real aircraft and to compare the results with those obtained from measuring vehicles.

Results demonstrated poor correlation. For instance, when a Tapley meter reads 0.36, a MU-meter reads 0.4, a SFT reads 0.43, a JBD 12...

To date, scientists have been unsuccessful in providing the industry with reliable and universal values. Tests and studies are still in progress.

As it is quite difficult to correlate the measured μ with the actual μ, termed as effective μ, the measured μ is termed as «reported μ«.

In other words, one should not get confused between:

1/ Effective μ: The actual friction coefficient induced from the tire/runway surface *interaction between a given aircraft and a given runway, for the conditions of the day.*

2/ Reported μ: Friction coefficient measured by the measuring vehicle.

Particularities of fluid contaminants

Moreover, the aircraft braking performance on a runway covered by a fluid contaminant (water, slush and loose snow) does not depend only on the friction coefficient μ.

As presented in chapters C2.2 and C2.3, the model of the aircraft braking performance (takeoff and landing) on a contaminated runway takes into account not only the reduction of a friction coefficient but also:

- The displacement drag

- The impingement drag

These two additional drags (required to be taken into account by regulations) require knowing the type and depth of the contaminant.

In other words, even assuming the advent of a new measuring friction device providing a reported μ equal to the effective μ, it would be impossible to provide takeoff and landing performance only as a function of the reported μ. Airbus Industrie would still require information regarding the depth of fluid contaminants.

C3.4.3 Data provided by Airbus Industrie

Please refer to § C6 for further details on contaminated runway performance provided by Airbus Industrie.

Hard contaminants

For hard contaminants, namely compacted snow and ice, Airbus Industrie provides the aircraft performance independently of the amount of contaminants on the runway. Behind these terms are some effective μ. These two sets of data are certified.

Fluid contaminants

Airbus Industrie provides takeoff and landing performance on a runway contaminated by a fluid contaminant (water, slush and loose snow) as a function of the depth of contaminants on the runway.

For instance, takeoff or landing charts are published for «1/4 inch slush», «1/2 inch slush», «1/4 inch water» and «1/2 inch water». For loose snow, a linear variation has been established with slush.

In other words, pilots cannot get the performance from reported μ or Braking

Action. *Pilots need the* ***type and depth of contaminant*** *on the runway.*

CORRELATION BETWEEN REPORTED μ AND BRAKING PERFORMANCE

Please, bear in mind:

Airports release a friction coefficient derived from a measuring vehicle. This friction coefficient is termed as «reported μ».

The actual friction coefficient, termed as «effective μ» is the result of the interaction tire/runway and depends on the tire pressure, tire wear, aircraft speed, aircraft weight and anti-skid system efficiency.

To date, ***there is no way to establish a clear correlation between the «reported μ» and the «effective μ».*** *There is even a poor correlation between the «reported μ» of the different measuring vehicles.*

It is then very difficult to link the published performance on a contaminated runway to a «reported μ« only. The presence of ***fluid contaminants*** *(water, slush and loose snow) on the runway surface* ***reduces the friction coefficient****, may lead to* ***aquaplaning*** *(also called hydroplaning) and creates an* ***additional drag.*** *This additional drag is due to the precipitation of the contaminant onto the landing gear and the airframe, and to the displacement of the fluid from the path of the tire. Consequently, braking and accelerating performance are affected. The impact on the accelerating performance leads to a limitation in the depth of the contaminant for takeoff.* ***Hard contaminants*** *(compacted snow and ice) only affect the braking performance of the aircraft by a reduction of the* ***friction coefficient.*** *Airbus Industrie publishes the takeoff and landing performance according to the* ***type of contaminant****, and to the* ***depth*** *of fluid contaminants."*

APPENDIX L

Correlation between measured friction coefficients and braking coefficients

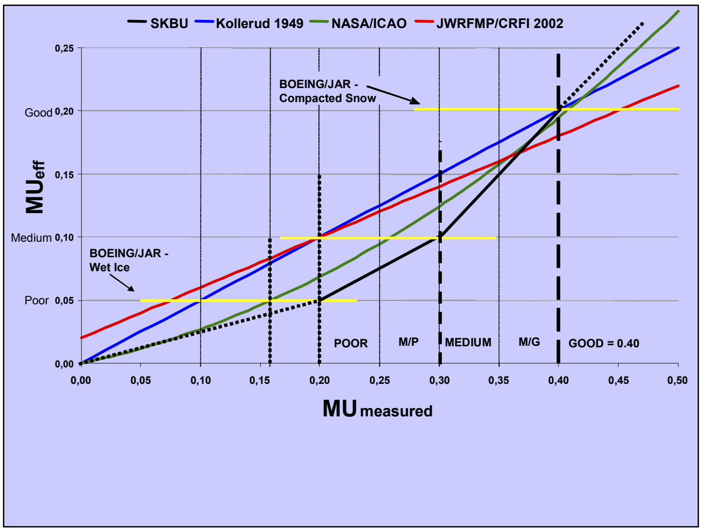


Figure 1. Correlation between measured μ and effective μ.(Norheim, Avinor 2006).

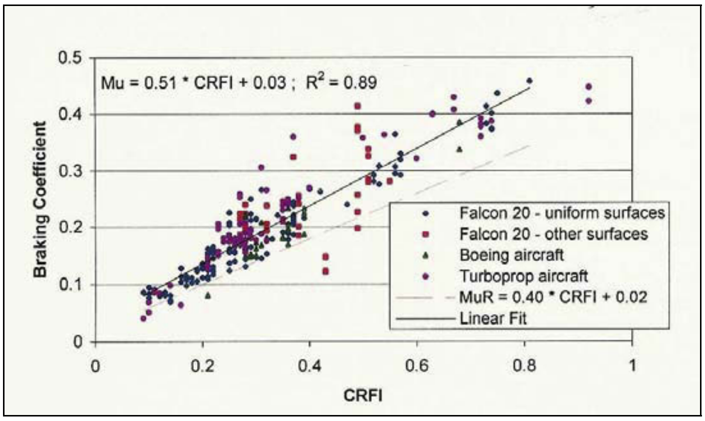


Figure 2. Airplane Braking Coefficient vs Canadian Runway Friction Index (CRFI, TC 2004).

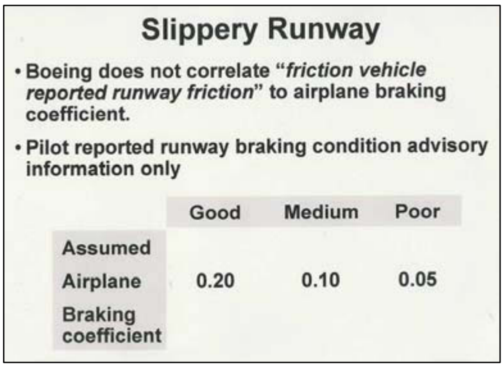


Figure 3. Boeing standard ABC (Boeing).

APPENDIX M

Excerpts from FAA Safety Alert For Operators (SAFO) 06012.

"e. Runway surface conditions may be reported using several types of descriptive terms including: type and depth of contamination, a reading from a runway friction measuring device, an airplane braking action report, or an airport vehicle braking condition report. Unfortunately, joint industry and multi-national government tests have not established a reliable correlation between runway friction under varying conditions, type of runway contaminants, braking action reports, and airplane braking capability. Extensive testing has been conducted in an effort to find a direct correlation between runway friction measurement device readings and airplane braking friction capability. However, these tests have not produced conclusive results that indicate a repeatable correlation exists through the full spectrum of runway contaminant conditions.

Therefore, operators and flight crews cannot base the calculation of landing distance solely on runway friction meter readings. Likewise, because pilot braking action reports are subjective, flight crews must use sound judgment in using them to predict the stopping capability of their airplane. For example, the pilots of two identical aircraft landing in the same conditions, on the same runway could give different braking action reports. These differing reports could be the result of differences between the specific aircraft, aircraft weight, pilot technique, pilot experience in similar conditions, pilot total experience, and pilot expectations. Also, runway surface conditions can degrade or improve significantly in very short periods of time dependent Approved by AFS-1 Page 7 on precipitation, temperature, usage, and runway treatment and could be significantly different than indicated by the last report. Flight crews must consider all available information, including runway surface condition reports, braking action reports, and friction measurements.

(1) Operators and pilots should use the most adverse reliable braking action report, if available, or the most adverse expected conditions for the runway, or portion of the runway, that will be used for landing when assessing the required landing distance prior to landing. Operators and pilots should consider the following factors in determining the actual landing distance: the age of the report, meteorological conditions present since the report was issued, type of airplane or device used to obtain the report, whether the runway surface was treated since the report, and the methods used for that treatment. Operators and pilots are expected to use sound judgment in determining the applicability of this information to their airplane's landing performance.

(2) Table 1 provides an example of a correlation between braking action reports and runway surface conditions:

Braking Action	*Dry (not reported)*	*Good*	*Fair/Medium*	*Poor*	*Nil*
Contaminant	*Dry*	*Wet* *Dry Snow (< 20mm)*	*Packed or Compacted Snow*	*Wet Snow* *Slush* *Standing Water* *Ice*	*Wet ice*

Table 1. Relationship between braking action reports and runway surface condition (contaminant type)

NOTE: Under extremely cold temperatures, these relationships may be less reliable and braking capabilities may be better than represented. This table does not include any information pertaining to a runway that has been chemically treated or where a runway friction enhancing substance has been applied."