民航意外調查機構
AAIA
Air Accident Investigation Authority

Runway Excursion (RE)

Investigation Report

Serious Incident to
Airbus A321-211, B-6366
Hong Kong International Airport
Hong Kong
24 May 2017

04-2022

AAIA Investigations

Pursuant to Annex 13 to the Convention on International Civil Aviation and the Hong Kong Civil Aviation (Investigation of Accidents) Regulations (Cap. 448B), the sole objective of the investigation and the Investigation Report is the prevention of accidents and incidents. It is not the purpose of the investigation to apportion blame or liability.

The then Chief Inspector of Accidents-cum-Director-General of Civil Aviation ordered an inspector's investigation into the serious incident in accordance with the provisions in Cap. 448B. As the powers of accident investigation were transferred to the Air Accident Investigation Authority (AAIA) with effect from 10 September 2018, the investigation of the serious incident was carried on by AAIA.

This serious incident investigation report contains information of an occurrence involving an Airbus A321-211, registration B-6366, operated by China Eastern Airlines Jiangsu Limited, which occurred on 24 May 2017.

The Civil Aviation Administration of China, being the investigation authority representing the State of Registry and the State of the Operator, and the Bureau d'enquêtes et d'analyses pour la sécurité de l'aviation civile (BEA), being the investigation authority representing the State of Design and the State of Manufacture, the Civil Aviation Department of Hong Kong, and China Eastern Airlines Jiangsu Limited, the aircraft operator, provided assistance to the investigation.

Unless otherwise indicated, recommendations in this report are addressed to the regulatory authorities of the State or Administration having responsibility for the matters with which the recommendation is concerned. It is for those authorities to decide what action is taken.

This Investigation Report supersedes all previous Preliminary Report and Interim Statements concerning this serious incident investigation.

All times in this Investigation Report are in Hong Kong Local Times unless otherwise stated.

Hong Kong Local Time is Coordinated Universal Time (UTC) + 8 hours.

Chief Accident and Safety Investigator

Air Accident Investigation Authority

Transport and Logistics Bureau

Hong Kong

July 2022

Synopsis

On 24 May 2017, a China Eastern Airlines (ICAO Code CES) Jiangsu Limited Airbus A321-211 aircraft, registration B-6366, operated a scheduled public transport services from Nanjing Lukou International Airport (ZSNJ) to Hong Kong International Airport (HKIA) (VHHH) with flight number CES765. The departure time was 0800 hrs local time.

After the aircraft touched down, Air Traffic Control (ATC) instructed it to vacate Runway 25R via Taxiway A4. The aircraft went past Taxiway A4 and when halfway between Taxiway A3 and A4, it deviated from the runway centreline and veered off to the grass verge on the right-hand side. The aircraft subsequently stopped with its nose landing gear and the right main landing gear resting on the grass at about 1051 hours.

The investigation team has made one safety recommendation.

Contents

1. FACTUAL INFORMATION

1.1. History of the Flight

(1) On 24 May 2017, a China Eastern Airlines Jiangsu Limited Airbus A321 aircraft, registration B-6366, operated a scheduled public transport service from Nanjing Lukou International Airport (ZSNJ) to Hong Kong International Airport (VHHH) with flight number CES765. The departure time was 0800 hrs local time (LT).

(2) The Pilot in command (PIC) was the 'pilot flying' (PF) in the left-hand seat while the co-pilot was the 'pilot monitoring' (PM) in the right-hand seat. The aircraft first made an approach into VHHH Runway (RWY) 07L. However, due to heavy rain and poor visibility, the flight crew initiated a missed approach at decision altitude. They requested another approach and the flight was then under the Air Traffic Control (ATC) radar vector for about 10 minutes while the landing runway was changed from RWY 07L to RWY 25R. They then conducted an instrument landing system (ILS) approach for RWY 25R. The aircraft touched down at 10:49:47 hrs.

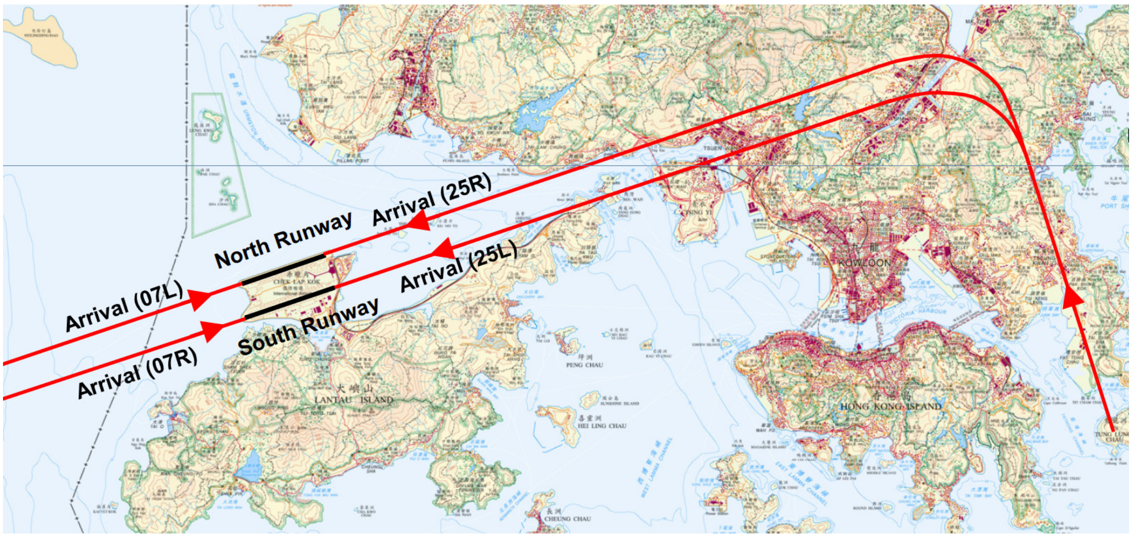


Figure 1: Arrival Flight Paths of HKIA

(3) On noting that CES765 did not exit the runway at Rapid Exit Taxiways (RET)[1] A6 and A5 after touchdown, ATC instructed it to vacate via Taxiway (TWY) A4 which was another RET. However, the aircraft also missed TWY A4 and veered off the runway centreline to the grass area on the right-hand side of the runway. The aircraft eventually stopped with its nose wheel and right-hand main landing gear (MLG) resting on the grass area

[1] Rapid exit taxiway is a taxiway connected to a runway at an acute angle and designed to allow landing aeroplanes to turn off at higher speeds than are achieved on other exit taxiways thereby minimizing runway occupancy times. (*ICAO Doc 4444 Air Traffic Management*)

slightly beyond the northern runway edge between TWYs A4 and A3 at about 1051 hrs (see Figure 2).

(4) After being informed by CES765 that the aircraft had veered off the runway, ATC immediately directed the following inbound flights to go around and notified the Airport Fire Contingent (AFC). The airport rescue services and vehicles then attended to the occurrence.

Figure 2: Aircraft Last Position

Photo 1: Aircraft Position after the Excursion

Photo 2: Rear View of the Aircraft

1.2. Injuries to Persons

There were two pilots, seven cabin attendants and 132 passengers on board the aircraft. No passengers were injured but two of them felt unwell and were sent to hospital.

<table>
<tr><td colspan="7">Injuries to Persons</td></tr>
<tr><td>Persons on board:</td><td>Crew</td><td>9</td><td>Passengers</td><td>132</td><td rowspan="2">Others</td><td rowspan="2">0</td></tr>
<tr><td>Injuries:</td><td>Crew</td><td>0</td><td>Passengers</td><td>0</td></tr>
</table>

Table 1: Injuries to Persons

1.3. Damage - Aircraft

There was no structural damage to the aircraft. Only the MLG tyres suffered minor damage.

1.3.1. MLG Tyres

(1) The MLG wheels are numbered from the left MLG to the right MLG and from 1 to 4 (see Figure 3). All four MLG tyres remained inflated and displayed adequate tread depth. The tyre pressure were measured after the incident and recorded in Table 2.

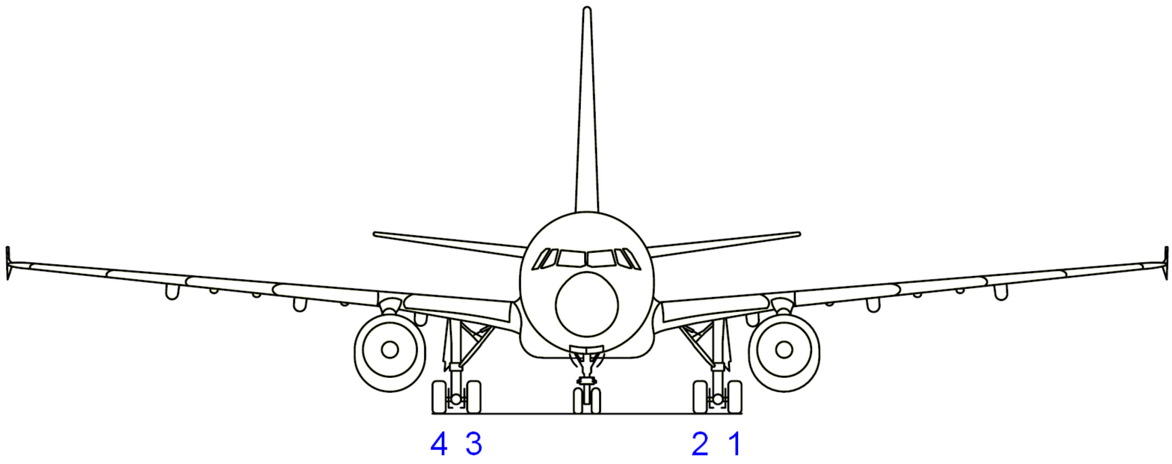


Figure 3: MLG Wheels Numbering

Position	Number	Pressure after the incident (PSI)	Date of Installation	Flight Cycles since Replacement
Left outboard	1	225	20 May 2017	18
Left inboard	2	230	28 Mar 2017	232
Right inboard	3	215	5 May 2017	77
Right outboard	4	230	20 May 2017	18

Limits: 220-230 PSI

Table 2: MLG Tyres Information

(2) Heavy abrasion and significant longitudinal scratches were found on their tread ribs. The left MLG tyres had evidence of skid damage and rubber reversion. The sidewalls of the right MLG tyres showed foreign object damage. Further details are in paragraph 2.6.2.

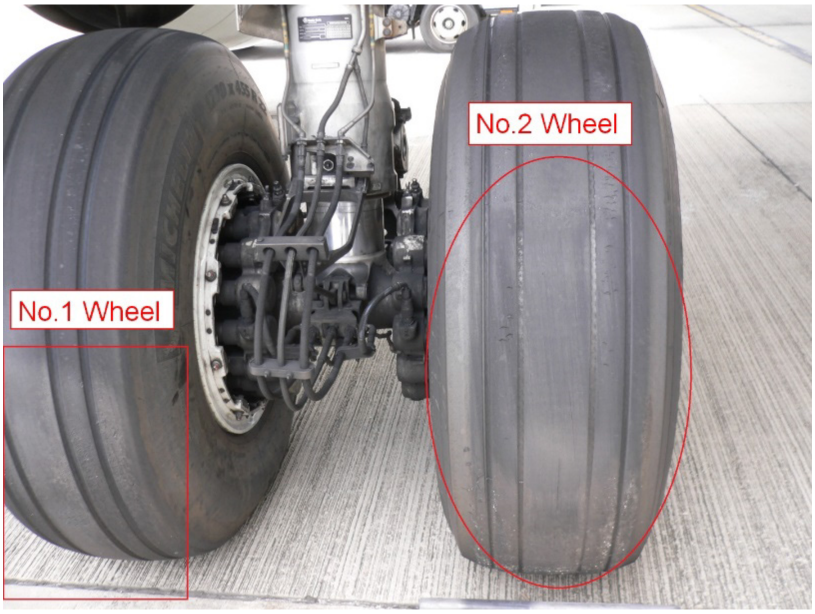


Photo 3: Damage on Left MLG Tyres

Photo 4: Significant Longitudinal Scratch Marks on No. 3 Tyre

Photo 5: Significant Longitudinal Scratch Marks on No. 4 Tyre

1.4. Other Damage

There was no other damage to objects other than the main wheel tyres.

1.5. Personnel Information

1.5.1. Flight Crew

(1) The PF and the PM held valid licences and medical certificates. Their information is in Section 7.2.

(2) Both the PF and the PM were interviewed by the investigation team after the incident.

1.6. Aircraft Information

1.6.1. Aircraft

(1) Airbus A321 is a narrow-body single-aisle aircraft with a retractable tricycle landing gear and is powered by two wing pylon-mounted CFM56-5B3 turbofan engines. It is a low-wing cantilever monoplane with a conventional tail unit having a single vertical stabilizer and rudder. The incident aircraft was fitted with four MLG wheels with radial tyres.

(2) The incident aircraft, serial number 3593, was delivered to the operator in July 2008. It had valid Certificate of Registration and Certificate of Airworthiness. The aircraft details are in Section 7.3.

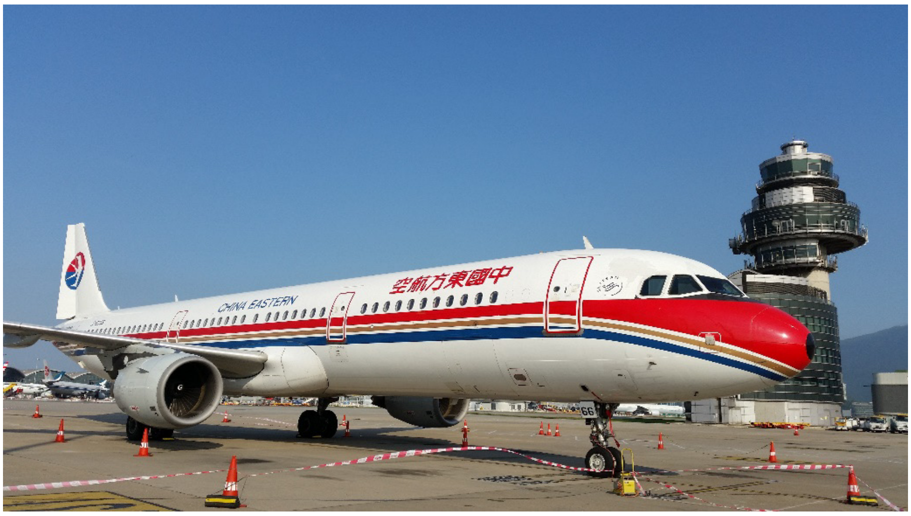


Photo 6: The Incident Aircraft

1.6.2. Maintenance History

The most recent scheduled maintenance check prior to the incident was an 'A' check performed on 5 May 2017. The aircraft operating as CES765 was dispatched with no defect entry in the aircraft technical logbook. A review of the aircraft's maintenance history did not identify any defects or recent maintenance actions that could contribute to the incident.

1.6.3. Post Flight Report

The Post Flight Report was printed out after the incident. There was no failure triggered during the subject flight.

1.6.4. Systems Used for Aircraft Deceleration during Landing

(1) Three systems are involved in deceleration once the aircraft is on the ground, namely:

- Ground spoilers
- Thrust reversers
- Wheel brakes

(2) The ground spoilers are normally set to deploy automatically on landing in order to reduce residual lift from the wings during the subsequent rollout and thus improve the effectiveness of the wheel brakes. Engine thrust reversers help the aircraft slow down just after touchdown, reducing wear on the brakes and enabling shorter landing distances. However, braking efficiency of engine thrust reversers drops rapidly when aircraft speed is below 70 kt.

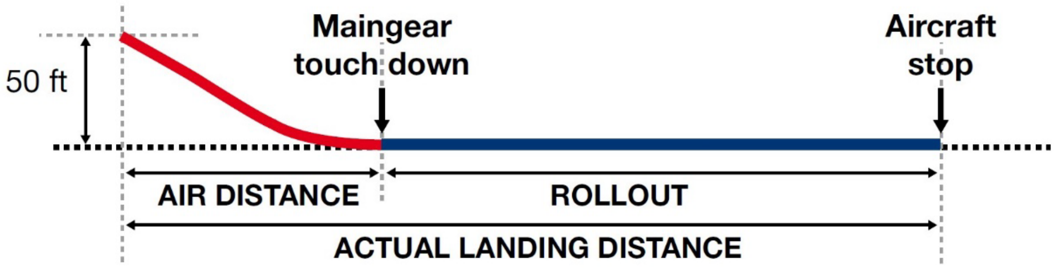


Figure 4: Rollout

1.6.5. Ground Spoilers

(1) When the aircraft touches down with at least one MLG and when at least one thrust lever is in the reverse sector, the ground spoilers automatically and partially deploy to ensure that the aircraft wheels are firmly on ground. Then, the ground spoilers automatically and fully deploy. This is the partial lift dumping function.

(2) The ground spoilers contribute to aircraft deceleration by increasing aerodynamic drag at high speed. Wheel braking efficiency is improved due to the increased load on the wheels. Additionally, the ground spoiler extension signal is used for autobrake activation.

1.6.6. Efficiency of Reverse Thrust

(1) The flight crew must select reverse thrust immediately after main landing gear touchdown.

(2) Thrust reversers are more efficient at high speeds. Below 70 kt, thrust reversers efficiency rapidly decreases. Below 60 kt with REV MAX (reverse maximum thrust) selected, engine stall may occur. Therefore, the Flight Crew Operating Manual (FCOM) recommends to reduce the reverse thrust to REV IDLE (reverse idle thrust) at 70 kt, and keep REV IDLE until taxi speed.

(3) The choice of reverse thrust depends on the runway conditions. On dry runways, the flight crew may select REV IDLE. On wet runways, the flight crew may select REV IDLE. On contaminated runways, the flight crew must select REV MAX. In an emergency case, the flight crew must keep REV MAX until full-stop of the aircraft.

(4) At taxi speed, and not above, the thrust reversers should be stowed before leaving the runway, in order to avoid foreign object ingestion.

1.6.7. Brakes and Antiskid

1.6.7.1. Flight Deck Controls

The flight deck controls for brakes and antiskid consist of the left and right brake pedals for each pilot, a landing gear panel on the forward panel for autobrake modes selection and ON/OFF selection of antiskid and Nose Wheel Steering, and a parking brake switch on the centre console. The flight deck brake pedal transmitters convert pedal angular displacement into electrical signals sending to the Brake and Steering Control Unit (BSCU) or the Alternate Brake Control Unit (ABCU) depending on the modes (Normal or Alternate) of braking.

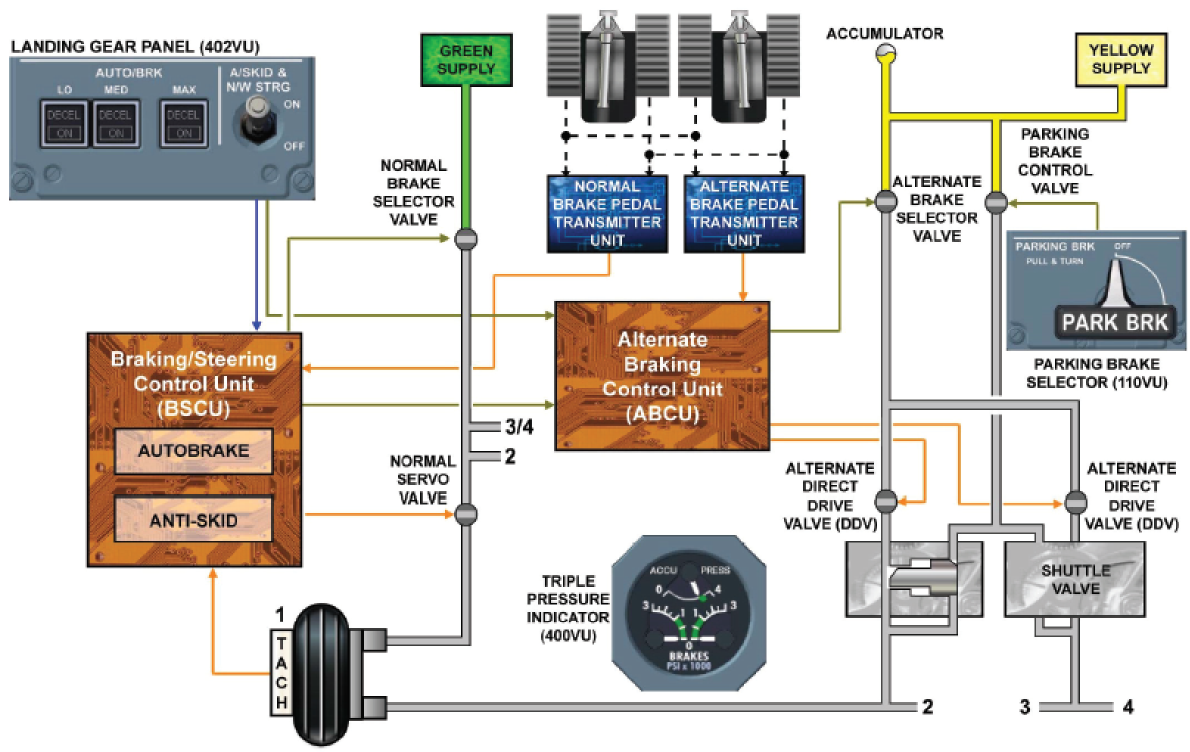


Figure 5: Braking System Schematic Diagram

1.6.7.2. Landing Gear Panel

(1) There are three pushbutton switches, namely LO, MED or MAX (low, medium or maximum), on the panel. The flight crew can press one of them to select the autobrake modes for the desired deceleration rate of the braking system.

Figure 6: Landing Gear Panel

(2) Each mode provides a target aircraft longitudinal deceleration rate on the ground without brake pedal operation. Either LO or MED autobrake can be armed for landing. In each case, the mode is initiated by ground spoiler deployment and, after a time delay, braking is automatically and progressively applied with the aim of producing a target deceleration rate.

Autobrake Mode	Preferred Use	Nominal Deceleration Rate	Time Delay
LO	long and dry runways	0.17 G (1.7 m/s^2 or 5.6 ft/s^2)	4 seconds
MED	short or contaminated runways	0.3 G (3 m/s^2 or 9.8 ft/s^2)	2 seconds

Table 3: LO and MED Autobrake Deceleration Rate and Time Delay

(3) The MAX autobrake mode is armed only for takeoff to apply maximum braking automatically in the event of a rejected takeoff.

(4) The Autobrake system will be deactivated if a flight crewmember applies enough deflection to at least one brake pedal.

(5) The Antiskid and Nose Wheel Steering (A/SKID & N/W STRG) switch activates the antiskid system and enables autobrake arming. When the switch is set to ON, antiskid and nose wheel steering are available and autobrake can be armed provided the Green hydraulic pressure is available. If the switch is set to OFF, antiskid, nose wheel steering, normal brake and autobrake are unavailable.

1.6.7.3. Brake System and Modes

(1) Each MLG has two wheels and each wheel is fitted with a multi-disc carbon brake unit. The brake system can operate in 4 modes, namely:

- Normal Braking (Manual and Autobrake, both with Antiskid)
- Alternate Braking with Antiskid
- Alternate Braking without Antiskid
- Parking/Ultimate Emergency Braking

(2) Braking is applied by hydraulically pressurising a number of cylinders on each brake unit, using the aircraft's Green hydraulic system in Normal Braking and the Yellow hydraulic system, backed up by an accumulator, in Alternate Braking and Parking/Ultimate Emergency Braking.

1.6.7.4. Normal Braking (Manual and Autobrake)

(1) Normal Braking has two modes of operation, namely automatic braking mode and manual braking mode. It is operative when the Green hydraulic pressure is available and A/SKID & N/W STRG switch is ON (see Figure 7). Antiskid is available for Normal Braking.

(2) Braking is electrically-controlled through the BSCU from:

- Pilot's pedals (manual braking mode, maximum brake pressure 2 537 psi), or
- Automatically activates (automatic braking mode) when:
    - On ground by the autobrake system, or
    - In flight when the landing gear lever is up.

(3) The antiskid system is controlled by the BSCU via the normal servo valves. There is no brake pressure indication in the cockpit in the Normal Braking mode.

(4) In the automatic braking mode, the BSCU uses the braking programme that is set to control the rate of the aircraft deceleration by controlling brake cylinder pressure to get the correct deceleration rate. This mode serves the purposes of reducing the braking distance in case of an aborted takeoff, and establishing and maintaining a selected deceleration rate during landing, thereby improving passenger comfort and reducing crew workload.

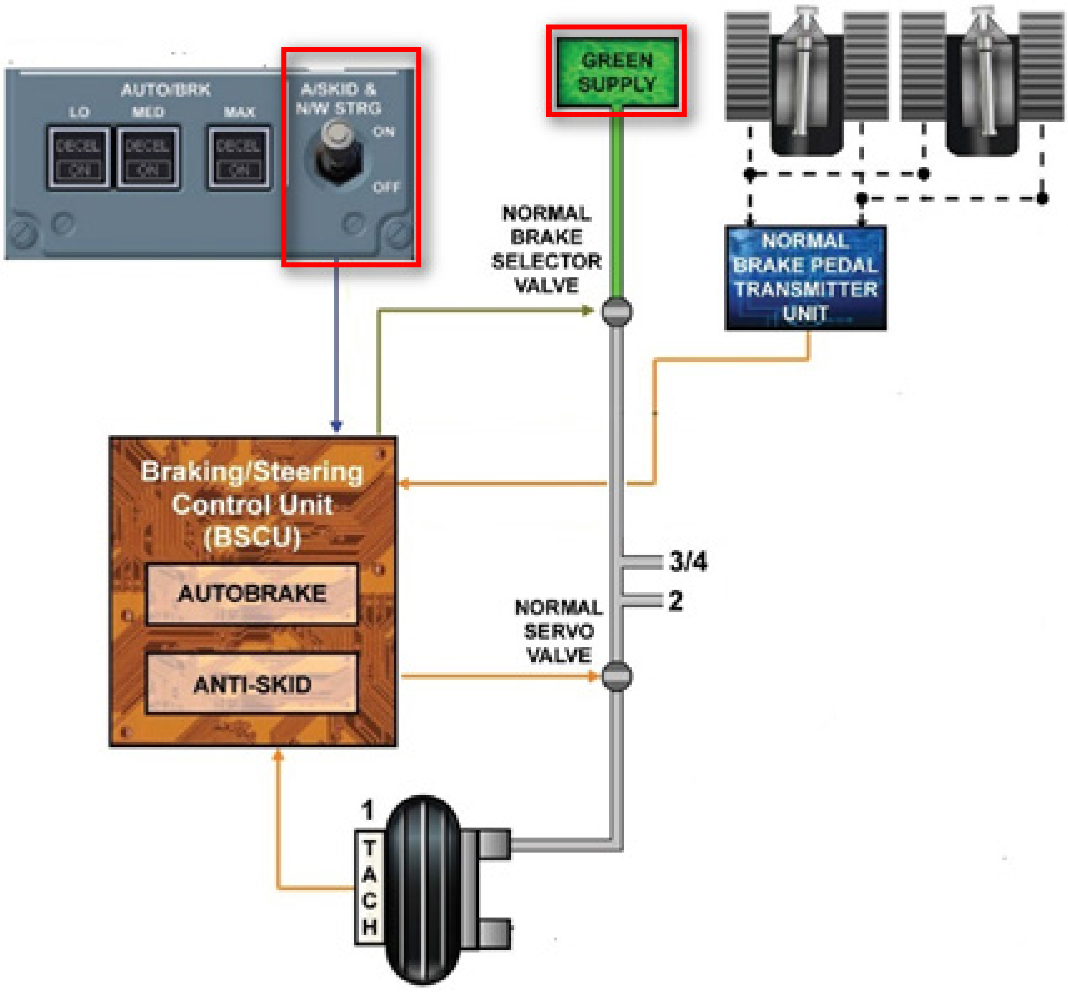


Figure 7: Normal Braking system

1.6.7.5. Alternate Braking with Antiskid

In Alternate Braking modes, the brake pedal demands are transmitted via a hydro-mechanical system and the brakes are pressurised by the Yellow hydraulic system. The detection of a fault in Normal braking and/or low Green hydraulic pressure will cause the system to switch to the 'Alternate with Antiskid' mode of which the BSCU continues to regulate antiskid while the ABCU will control the brake pressure. The braking pressure is read on the triple indicator.

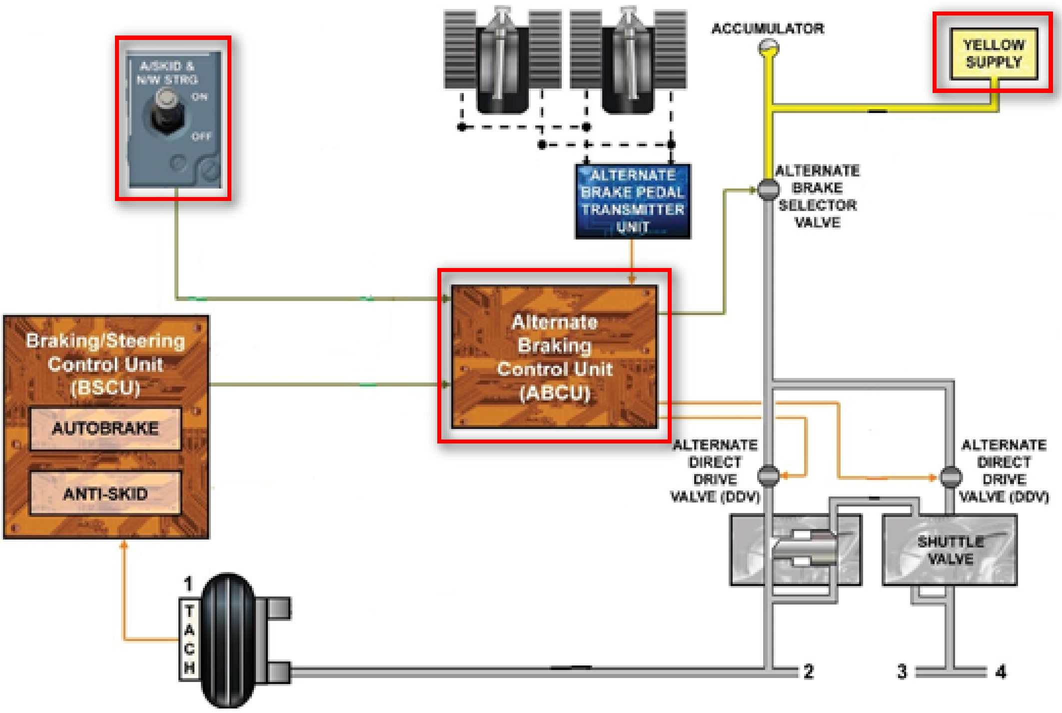


Figure 8: Alternate Braking system

1.6.7.6. Alternate Braking without Antiskid

If the A/SKID & N/W STRG switch is selected to OFF, a BSCU failure is detected, or the hydraulic pressure is low (brakes being supplied by the brake, accumulator only), the Alternate without Antiskid mode becomes active and brake cylinder pressure is directly proportional to brake pedal angle. The maximum brake pressure is limited to 1 000 psi. The flight crew must refer to the triple pressure indicator to limit brake pressure in order to avoid locking a wheel. With the accumulator pressure only, a maximum of 7 full brake pedal applications can be made.

1.6.7.7. Parking / Ultimate Emergency Braking

The Yellow hydraulic system or the brake accumulators supply brake pressure via the shuttle valves for the parking. Putting on the parking brake deactivates the other braking modes and the antiskid system. The parking brake can also be used as the last resort to stop the aircraft if the loss of braking occurs during landing.

1.6.7.8. Antiskid System

(1) The Antiskid system is intended to prevent the MLG wheels locking individually by reducing brake pressure should the tyre adhesion to the runway become marginal. It aims to give the maximum braking efficiency, and therefore the overall braking of the aircraft, as it keeps each individual wheel at the maximum deceleration rate avoiding a skidding configuration. The system deactivates automatically when the aircraft's ground speed is below 20 kt.

(2) The BSCU computes a reference speed based on the MLG wheel speeds while aircraft deceleration is determined from three Air Data Inertial Reference Units (ADIRUs). This reference speed is compared to each MLG wheel speed and if the difference is too large (wheel speed < reference speed) then the antiskid is activated.

1.6.7.9. Nose Wheel Steering

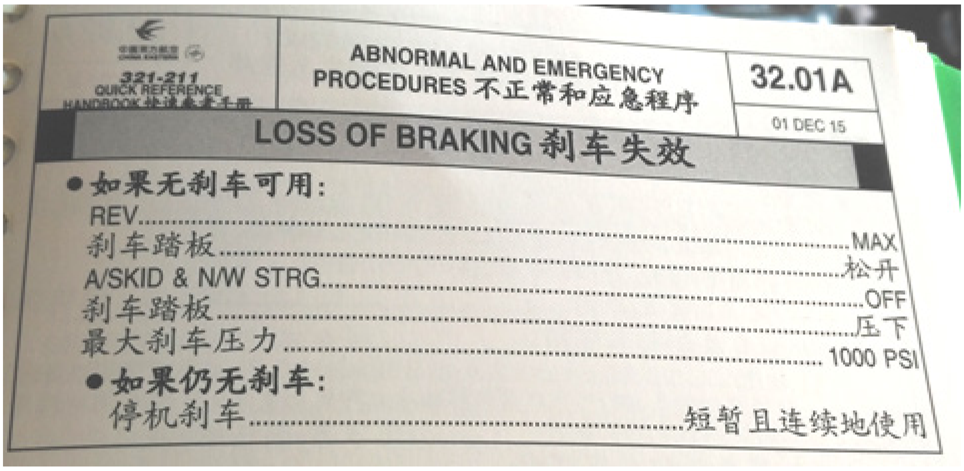
During rollout, rudder pedals are used to steer the aircraft on the runway centreline. At high speed the rudder ensures the steering function. When speed reduces below 100 kt, command by pedal will take over nose wheel steering function. The nose wheel steering is operated by the Green hydraulic system and controlled by the BSCU in response to demands from each pilot's steering tiller, the rudder pedals and the autopilot. Hand tiller operation provides maximum nose wheel steering angles of ±75 degrees. Selecting the A/SKID & N/W STRG switch (see Figure 6) to OFF deactivates the nose wheel steering system and renders the nose wheel free to turn under the effect of the aircraft motion.

Figure 9: Nose Wheel Steering Tillers (Pilot and Co-pilot)

1.6.7.10. Loss of Braking Abnormal and Emergency Procedures

(1) If the flight crew does not perceive aircraft deceleration when required, they will apply the Loss of Braking procedure in the Quick Reference Handbook (QRH) from memory because of the urgency of the situation. The procedure includes steps of using full reverse thrust, setting the A/SKID & N/W STRG switch to OFF to revert to alternate braking, and if there is still no braking, applying short and successive parking brake.

(2) Full reverse thrust may be used until the aircraft comes to a complete stop. Below 70 kt, when the flight crew considers that the aircraft can stop on the runway, they should set idle reverse thrust. In addition, they must modulate brake pressure at, or below, 1 000 psi in order to avoid wheel locking.


321-211 QUICK REFERENCE HANDBOOK 快速参考手册

ABNORMAL AND EMERGENCY PROCEDURES 不正常和应急程序

32.01A

01 DEC 15

LOSS OF BRAKING 刹车失效

● 如果无刹车可用:

REV..........MAX

刹车踏板..........松开

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

刹车踏板..........压下

最大刹车压力..........1000 PSI

● 如果仍无刹车:

停机刹车..........短暂且连续地使用

Photo 7: Loss of Braking Procedures in QRH

(3) The English translation of the above procedures is as follows.

Chinese	English
● 如果无刹车可用：	● IF NO BRAKING AVAILABLE :
REV...MAX	REV ....MAX
刹车踏板.................................松开	BRAKE PEDALS ....RELEASE
A/SKID & N/W STRG.............OFF	A/SKID & N/W STRG ....OFF
刹车踏板.................................压下	BRAKE PEDALS ....PRESS
最大刹车压力…..........……1000 PSI	MAX BRK PR ....1000 PSI
● 如果仍无刹车：	● If STILL NO BRAKING :
停机刹车..............短暂且连续地	PARKING BRAKE ....SHORT AND SUCCESSIVE APPLICATIONS

Table 4: Loss of Braking Procedures (English Translation)

1.7. Meteorological Factors

(1) In the morning of the day of incident, a trough of low pressure brought torrential rain and squally thunderstorms to the coastal area of the Guangdong province. Hong Kong including the airport was affected by heavy or very heavy rain and thunderstorms. Different rainstorm signals were issued by the Hong Kong Observatory (HKO) as listed in the table below, including the only Black Rainstorm Warning in 2017.

Local Time (hrs)	Rainstorm Signals
0640 to 0915	 [2]
0915 to 1130	 [3]
1130 to 1230	 [4]
1230 to 1500	

Table 5: Rainstorm Signals from 0640 hrs to 1500 hrs Local Time

(2) HKO satellite images from 0900 hrs to 1154 hrs showed rain echoes over and around the airport. Aerodrome thunderstorm warning effective from 0655 hrs to 1435 hrs was issued by the Airport Meteorological Office (AMO). The incident took place at 1051 hrs when the RED rainstorm warning was effective. A total of 40.9 mm of rain was recorded at the airport in the 60 minutes prior to the incident. The weather radar pictures from 1018 hrs to 1048 hours are shown in Appendix 10.1.

(3) In addition to half hourly aerodrome routine meteorological reports (METAR) for VHHH, multiple aerodrome special meteorological reports (SPECI) were issued by the AMO between 0900 hrs and 1200 hrs to disseminate significant variation of the reported meteorological elements brought about by heavy passing showers and thunderstorms.

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2 Heavy rain has fallen or is expected to fall generally over Hong Kong, exceeding 30 millimetres in an hour, and is likely to continue.

3 Heavy rain has fallen or is expected to fall generally over Hong Kong, exceeding 50 millimetres in an hour, and is likely to continue.

4 Very heavy rain has fallen or is expected to fall generally over Hong Kong, exceeding 70 millimetres in an hour, and is likely to continue.

METAR VHHH 240200Z 33011KT 300V360 1700 1400E R07R/P2000N R25L/P2000D R07L/1800N R25R/1600N +TSRA +SHRA FEW010CB SCT025 26/25 Q1007 WS R07R TEMPO 2000 TSRA SHRA FEW010CB SCT020=
SPECI VHHH **240212Z** 31013KT 280V340 1200 0600E R07R/P2000D R25L/P2000D R07L/1500D R25R/1400D +TSRA +SHRA FEW010CB SCT025 25/25 Q1007 TEMPO 1600 TSRA SHRA FEW010CB SCT020=
SPECI VHHH 240229Z 35022G33KT 1200 0900E R07R/2000U R25L/1500D R07L/1400U R25R/1200N +TSRA +SHRA FEW010CB SCT025 25/24 Q1007 TEMPO 1600 TSRA SHRA FEW010CB SCT020=
METAR VHHH 240230Z 35023G33KT 0900 0550N R07R/1700N R25L/1500D R07L/1300N R25R/1200N +TSRA +SHRA FEW010CB SCT025 25/24 Q1007 TEMPO 1600 TSRA SHRA FEW010CB SCT020=
ATIS[5] HONG KONG ARRIVAL INFORMATION **B** AT TIME 0230 ARRIVAL RUNWAY 25R SIG WS FCST RWY SFC WET WIND 340 DEG 20 KT VISIBILITY 2000 METRES RVR[6] 800 METRES TS WITH HVY RAIN CLOUD FEW CB 1000 FT SCT 2500 FT TEMPERATURE 25 DEWPOINT 25 QNH 1007 HPA EXP SIG TAILWIND ON BASELEG ACKNOWLEDGE INFORMATION B ON FIRST CONTACT WITH APPROACH
SPECI VHHH 240235Z 35021G33KT 0650 0500E R07R/1900U R25L/1200D R07L/1400U R25R/1100N +TSRA +SHRA FEW010CB SCT025 25/23 Q1008 TEMPO 1600 TSRA SHRA FEW010CB SCT020=
SPECI VHHH 240241Z 35015KT 320V030 3300 R07R/P2000U R25L/1300U R07L/P2000U R25R/1700U +TSRA +SHRA FEW010CB SCT025 25/23 Q1008 TEMPO 1600 TSRA SHRA FEW010CB SCT020=
ATIS HONG KONG ARRIVAL INFORMATION **C** AT TIME 0241 ARRIVAL RUNWAY 25R SIG WS FCST RWY SFC WET WIND 350 DEG 15 KT MAX 30 KT VISIBILITY 3000 METRES TS WITH HVY RAIN CLOUD FEW CB 1000 FT SCT 2500 FT TEMPERATURE 25 DEWPOINT 23 QNH 1008 HPA EXP SIG TAILWIND ON BASELEG ACKNOWLEDGE INFORMATION C ON FIRST CONTACT WITH APPROACH

Table 6: METAR, SPECI, and ATIS between 1000 hrs and 1041 hrs

(4) The subject A321 carried out a go around RWY 07L at 1020 hrs. SPECI at 1012 hrs indicated the following: surface wind 310 degrees 13 kt variable between 280 and 340 degrees, visibility 1 200 m, RWY 07L RVR 1 500 m

[5] ATIS – Automatic Terminal Information Service

[6] RVR - Runway Visual Range

decreasing, thunderstorm rain and shower of rain, and 1-2 oktas cumulonimbus at 1 000 ft above aerodrome level.

(5) ATIS Arrival information 'B' at 1030 hrs showed that there would be significant wind shear at RWY 25R, **runway surface wet**, surface wind 340 degrees 20 kt, visibility 2 000 m, RVR 800 m, **thunderstorm with heavy rain**, 1-2 oktas cumulonimbus at 1000 ft, and a warning for pilots to expect significant tailwind on base-leg.

(6) Similarly, ATIS Arrival information 'C' at 1041 hrs forecasted that there would be significant wind shear at RWY 25R, **runway surface wet**, surface wind 350 degrees 15 kt gusting up to 30 kt, visibility 3 000 m, **thunderstorm with heavy rain**, 1-2 oktas cumulonimbus at 1 000 ft, and a warning for pilots to expect a significant tailwind on base-leg.

(7) SPECI at 1041 hrs indicated the following: surface wind 350 degrees 15 kt variable between 320 and 030 degrees, visibility 3 300 m, RWY 25R RVR 1700 m increasing, thunderstorm rain and shower of rain, and 1-2 oktas cumulonimbus at 1 000 ft above aerodrome level. Almost continuous Wind Shear Alerts were generated by the Wind Shear and Turbulence Warning System (WTWS) from 1021 hrs till 1030 hrs indicating either lifting wind shear at 2 nautical miles final RWY 25R or sinking wind shear over the runway.

(8) At 1041 hrs surface wind was between 320 degrees and 030 degrees. This indicated that there was a crosswind from the right for aircraft landing on RWY 25R. When ATC cleared the subject A321 to land, they also advised that the wind was from 020 degrees at 16 kt. The aircraft then landed on RWY 25R at 1051 hrs.

1.8. Navigation Aids

There were no reports of abnormal operation of any ground-based navigation aids or aerodrome visual ground aids at the time of approach and landing of CES765 on RWY 25R.

1.9. Communications

The A321 was equipped with VHF radio communication systems which were serviceable. All communications between Hong Kong ATC and the aircraft were recorded by the Digital Recording System[7] (DRS) of the Air Traffic Management System which supported Hong Kong ATC in the provision of air navigation services. There was no interruption to such communications.

[7] Digital Recording System is an ATC system that provides recording, playback and real time monitoring functions for radio transmissions, intercom and audio reception at controller workstations from the headset microphone and the surrounding area.

1.10. Aerodrome Information

1.10.1. The Airport

(1) The HKIA is operated by the Airport Authority Hong Kong (AAHK) which is granted an aerodrome licence by the Civil Aviation Department (CAD). The Airport Standards Division (APSD) of CAD is responsible for the safety oversight on the performance of AAHK to ensure its compliance with the aerodrome licensing requirements.

(2) The HKIA has two parallel runways, namely the North Runway and the South Runway, running northeast to southwest. The two runways are normally operated in a segregated mode with the North Runway dedicated for arrivals and the South Runway dedicated for departures. The direction of aircraft landing at the HKIA primarily depends on the prevailing wind directions for safety and operational reasons. In general, it would be an operational preference for arrivals to land with a headwind. The North Runway is designated RWY 07L or RWY 25R (see Figure 1). It can be used for the International Civil Aviation Organization (ICAO) Code F aircraft (Airbus 380, B747-8 and Antonov 124) operations and has a 7.5 m wide shoulder on each side.

1.10.2. Runway Physical Characteristics

(1) Both runways are grooved and have 1.5% transverse slope for drainage. The details of the North Runway are extracted from the Aeronautical Information Publication of Hong Kong (AIP HK).

1	2	3	4	5	6
RWY Designator	*True and MAG BRG*	*Dimensions of RWY (m)*	*Strength (PCN) and surface of RWY - SWY*	*THR Co-ordinates*	*THR ELEV and highest point of TDZ of Precision APP RWY*
07L	070.90°T 073.90°M	3800 x 60	72/F/B/W/T Asphalt	221839.30N 1135352.67E	22FT
25R	250.90°T 253.90°M	3800 x 60	72/F/B/W/T Asphalt	221916.04N 1135546.69E	22FT
7	8	9	10	11	12
Slope of RWY-SWY	*SWY dimensions (m)*	*CWY dimensions (m)*	*Strip dimensions (m)*	*OFZ*	*Remarks*
07L: NIL	NIL	300 x 150	3920 x 300	NIL	Full length of RWY is grooved RESA 240 x 150 m
25R: NIL	NIL	300 x 150	3920 x 300	NIL	Full length of RWY is grooved RESA 240 x 150 m

Figure 10: The North Runway Physical Characteristics

(2) The Pavement Classification Number (PCN) 72/F/B/W/T can be interpreted as follows.

72	The load-carrying capacity of the pavement is 72 (no units).
F	The pavement is of a flexible (asphalt) design.
B	The strength of what is underneath the pavement section is Medium Strength – California Bearing Ratio (CBR) 10 (for CBR between 8% and 13%).
W	There is no maximum tyre pressure limit for the pavement.
T	The method through which the first value (72) was obtained is by technical evaluation.

Table 7: Interpretation of the PCN of the North Runway

(3) The following table identifies the declared distances of the North Runway.

Runway	Take-off run available (TORA)	Take-off distance available (TODA)	Accelerated stop distance available (ASDA)	Landing distance available (LDA)
07L	3 800 m	4 100 m	3 800 m	3 627 m
25R	3 800 m	4 100 m	3 800 m	3 626 m

Table 8: North Runway Declared Runway Distances

1.10.3. Vacating Runway for Arrival Flights

(1) AIP HK AD 1.1 *Aerodrome/Heliport Availability* dated 28 July 2011 stipulates that pilots should vacate the runway as quickly as practicable to enable ATC to apply minimum spacing on final approach thereby maximising runway utilisation and minimising the occurrence of missed approaches. To facilitate minimum runway occupancy time, each runway has multiple RETs that comply with ICAO design specifications. Pilots should vacate via the first available RET commensurate with operational conditions, or as instructed by ATC.

(2) The landing distance to each RET of RWY 25R as published in AIP HK is listed below. RET A4 and A6 have Rapid Exit Taxiway Indicator Lights (RETILs) to assist pilots to assess the distance to the exit taxiway in low visibility or at night. The RETILs are six yellow lights adjacent to the centreline, three indicating 300 metres, two, 200 metres and one, 100 metres to go to the exit taxiway.

Rapid Exit Taxiway	Landing Distance
A6*	1 962 m
A5	2 432 m
A4*	2 902 m

** With RETILs*

Table 9: Landing Distance to Each RET of RWY 25R

1.10.4. Runway Maintenance at HKIA

(1) The AAHK has in place a programme to conduct runway friction measurement and rubber removal. In 2017, the schedule of runway friction run was about every 10 days. Between April and September, rubber removal at the touchdown zone of RWY 07L and RWY 25R was conducted on quarterly basis and semi-annually basis respectively.

(2) If the scheduled runway friction measurement could not be conducted due to weather, etc., a backup runway friction measurement should be conducted on the next runway closure.

(3) Relevant paragraphs concerning runway friction measurement stated in the AIP HK AD 1.1 are extracted below:

"***16 Runway Friction Measuring Device and Runway Friction Level***

*16.1 Runway surface friction at Hong Kong is measured by means of a Griptester in accordance with recognised procedures. Runs are carried out at a speed of 65 km/hour regularly on a dry runway surface using a self-watering device giving a controlled depth of 1 mm of water to monitor the effectiveness of the rubber deposit removal programme and surface wear and tear. Should the friction value fall to **0.43** or less the runway will be notified as liable to be slippery when wet.*

16.2 If and when such notification is given, there may be a significant deterioration both in aircraft stopping performance and directional control when the runway is wet. Takeoff or landing should then be considered only if the distances available equal to or exceed those required for slippery conditions as determined in the Aeroplane Flight Manual.

16.3 If a pilot experiences a significant degradation of the braking action, it should immediately be reported to ATC for relay to subsequent landing aircraft and for follow-up action by the airport authority."

(4) When the friction of a particular portion of the touchdown zones is found to be below this published value, rubber removal at the concerned chainage

will be immediately arranged to restore to a friction value above 0.43. If rubber removal cannot be arranged due to weather conditions, such information will be reported by AAHK to CAD and promulgated by a Notice to Airmen (NOTAM)[8]. If the friction value of a particular chainage outside the touchdown zone falls below 0.43, AAHK will alert ATC to request for braking action reports from the arrival flights. AAHK will also conduct adhoc pavement inspection and take necessary follow-up actions.

(5) The friction value (0.43 here) is dependent on the specific friction measurement equipment.

(6) Where friction equipment is not available at the airport, according to Paragraph 1 of Appendix 2 of the ICAO Doc 9137 Airport Services Manual Part 2 *Pavement Surface Conditions*, Fourth Edition – 2002, the aerodrome operator should conduct periodic visual maintenance inspection surveys to ensure that the pavement surface is acceptable for aeroplane operations.

1.10.5. Maintenance Records of RWY 07L Touchdown Zone

(1) Chainage numbers are used to identify the runway sections for friction measurement and rubber removal purposes (see Figure 11). According to the AAHK records, two runway friction measurement were carried out at the RWY 07L touchdown zone at 0130 hrs on 21 May 2017 and 24 May 2017 respectively. The friction values between Chainage 100 and 800 are presented in the following table.

Date	101-200	201-300	301-400	401-500	501-600	601-700	701-800	Average
21 May 2017	0.55	0.60	0.15	0.10	0.08	0.13	0.29	0.27
24 May 2017	0.67	0.47	0.15	0.11	0.15	0.21	0.51	0.32

Table 10: Records of Runway Friction Measurement

(2) Chainage 100 is abeam the centreline of TWY A3, Chainage 300 is abeam the mid-point of TWY A4. Chainage 500 is abeam the beginning of TWY A4 exit. Chainage 800 is abeam the midpoint of TWY A5.

(3) As noted in (1) and Table 10 above, according to AAHK, they conducted friction measurement of the North Runway on 21 May 2017 at 0130 hours. This was done using the friction measurement equipment “Findlay Irvine Griptester”. The readings of the Griptester showed friction measurements

[8] NOTAM is a notice distributed by means of telecommunication containing information concerning the establishment, condition or change in any aeronautical facility, service, procedure or hazard, the timely knowledge of which is essential to personnel concerned with flight operations.

for some 100 m portions of the touchdown zone as low as 0.10 and 0.08, which were approximately 5 times lower than the minimum limit of 0.43 and which has never been recorded since the airport opening on 6 July 1998, as shown in Table 10 above. AAHK considered that such readings were abnormal, which suggested that the Griptester had malfunctioned and was giving inaccurate readings. Hence, in accordance with the procedure prescribed in Paragraph 1 of Appendix 2 of the ICAO Airport Services Manual Part 2 for situations where friction equipment is not available at the airport, AAHK conducted a visual maintenance inspection survey of the runway surface. The visual inspection confirmed the North Runway surface condition was normal. The North Runway was re-opened for air traffic at 0359 hours on 21 May 2017.

(4) AAHK instructed its contractor to carry out a complete health check and full calibration for their Griptesters on 22 May 2017[9] and the results were satisfactory. The Griptesters were released by the contractor again on 24 May 2017 for another friction measurement.

(5) As also noted in (1) and Table 10 above, friction measurement of North Runway conducted at 0130 hours on 24 May 2017 showed an average value at RWY 07L touchdown zone of 0.32. Values of some 100m portions of the 07L touchdown zone were as low as 0.11 and 0.15. AAHK again considered the readings inaccurate and conducted a joint visual inspection survey by their operation and professional engineering maintenance staff at 0700 hours that day. According to AAHK, the results of the joint visual inspection survey indicated that the pavement condition was normal with some rubber deposit at certain concerned portions of RWY 07L touchdown zone, but rubber deposit at those portions were not significantly different from other portions of the runway with normal friction values. AAHK considered the North Runway surface condition was safe for operations, and it was re-opened for air traffic at 0744 hours.

(6) There were no runway rubber removal activities between the two dates.

(7) As the low friction values from the Griptester of certain concerned portions of the North Runway could not be reconciled with the result of the visual inspection surveys conducted in accordance with ICAO guidance, AAHK considered the Griptester's values recorded on 21 and 24 May 2017 were abnormal which AAHK believed was resulted from an equipment malfunction, meaning that such readings could not be relied upon. For this reason, information of the average runway friction value at RWY 07L

[9] According to AAHK, the calibration was carried out by its contractor in accordance with the Operations & Maintenance Manual. It should be noted that such calibration is different from an annual service and calibration conducted by the Griptesters' original equipment manufacturer Findlay Irvine Ltd. According to the information provided by AAHK, an annual service and calibration of the Griptesters by Findlay Irvine Ltd is more comprehensive in scope, and is recommended to be carried out on a standard test track in the United Kingdom.

touchdown zone having been recorded by the Griptester at below 0.43 was not conveyed to CAD.

1.10.6. Issuance of NOTAM for the Runway Conditions

Since CAD had not been notified of the below average friction values tabulated in paragraph 1.10.5 (1), no NOTAM was issued for the runway conditions by CAD before this incident. After the occurrence, AAHK reported the low friction values to CAD. NOTAM A1133 was issued at around 1948 hrs on the same day advising that the runway might be liable to be slippery when wet due to persistent inclement weather. It was subsequently extended twice (with NOTAMs A1199 and A1649) to last until the end of July 2017.

1.10.7. Water on the Runway

The photos taken during the rescue phase shortly after the incident, such as Photos 8 and 9, showed noticeable water on the runway in the vicinity of the last position of the aircraft. Photo 8 showed the reverse angle of Photo 9.

Photo 8: Water Accumulated in the Vicinity of the Aircraft Last Position

1.10.8. Braking Action Report

In the morning of the incident day, ATC received a braking action report from the third to last landing aircraft on RWY 07L stating that it was ‘poor’. The details are presented in paragraph 1.18.7.1.

1.11. Flight Recorders

1.11.1. Flight Data Recorder

The incident aircraft was equipped with a Honeywell solid-state flight data recorder (FDR), part number 980-4700-042. The unit was undamaged. The data was successfully downloaded. Selected flight data is presented in Section 10 Appendix 10.2.

1.11.2. Cockpit Voice Recorder

The incident aircraft was equipped with a Honeywell solid-state cockpit voice recorder (CVR), part number 980-6022-001. The unit was not damaged in the incident. The data was also downloaded successfully. According to the recording, prior to landing the flight crew did not make any call to ATC that they preferred to use the full length of the runway.

1.11.3. Critical Points of the Rollout

(1) For the analysis and discussion of the flight data, the rollout after landing is divided into three sections and seven critical points, namely A (the touchdown point) to G (the last position of the aircraft), have been selected (Figure 11). Section 1 is from point A to point B, Section 2 is from point B to point F, and Section 3 is from point F to point G.

Figure 11: Critical Points of the Rollout

(2) The letters 'A' to 'F' represent the critical locations which will be discussed in this report.

Point	Distance from threshold (approx.)	Aircraft Rolled Past Time (Hrs)	Ground Speed of Incident Aircraft (kt)
A	690 m (2 264 ft)	10:49:47	148 kt
B	1 950 m (6 400 ft)	10:50:06	90 kt
C	2 320 m (7 612 ft)	10:50:15	56 kt
D	2 384 m (7 822 ft)	10:50:18	50 kt
E	2 535 m (8 317 ft)	10:50:22	50 kt
F	2 870 m (9 416 ft)	10:50:36	42 kt
G	3 170 m (10 400 ft)	10:50:55	0 kt

Table 11: Critical Points of the Rollout

(3) The PIC indicated in the interview that the calculated landing distance was 2800 m. It was 102 m shorter than that of RET A4 (see Table 9).

1.11.4. FDR Data Summary

(1) The recorded data indicated that the descent and approach to RWY 25R were uneventful. The aircraft was configured for landing with full flap, autopilot engaged, ground spoilers armed and autobrake armed in the LO mode. The crew flew an ILS approach to RWY 25R, with the autopilot remaining engaged until 580 ft Above Ground Level (AGL). The final approach was stabilised with a tail wind between 5 kt and 8 kt coupled with a crosswind from the right of 10 kt to 17 kt. The airspeed at 50 ft AGL was 144 kt computed airspeed and the autothrust system remained engaged.

(2) The spoilers fully deployed soon after the touchdown and remained extended until the ground speed dropped to about 40 kt.

(3) The thrust levers were put to maximum reverse thrust after touchdown and used for about 4 seconds. Then the reverse thrust was gradually reduced and set to REV IDLE when the aircraft reached point B. The thrust levers were put to FWD IDLE (forward idle thrust) 12 seconds later. At 10:50:44 hrs when the aircraft was between point F and point G, the thrust levers were momentarily moved forward.

(4) The autobrake was activated after touchdown for 20 seconds with a deceleration around 0.18 G, which is nominal for the LO mode. At point B, the autobrake was disconnected due to brake pedal inputs. During the

first 10 seconds of brake pedal inputs, the deceleration was around 0.2 G with a peak of 0.28 G. At point C, the rate of deceleration started to drop. The brake pedals were released for four seconds between point D and point E, and the deceleration further decreased to about 0.02 G. When the brake pedal inputs were provided again, the deceleration increased to between 0.05 G and 0.1 G. However, despite some maximum brake pedal inputs the deceleration remained low. At point F, the flight crew set the A/SKID & N/W STRG switch to OFF. This action meant that the antiskid function was no longer available and the nose wheel steering could only be achieved by differential braking. The aircraft started to deviate to the right, and differential braking and full rudder deflection to the left were applied.

(5) The aircraft left the runway at about 40 kt and stopped at point G.

1.11.5. Hydraulic and Brake System Parameters

In addition to brake pedal deflections and brake pressure, the FDR recorded a number of parameters relating to the hydraulic and the braking systems. The parameters indicated that there were no faults on the hydraulic, braking and antiskid systems during the event.

1.11.6. Braking and Steering Control Unit Data

The BSCU stores operational data, which includes fault codes for troubleshooting, within the unit. The data for the incident flight was analysed by Airbus.

1.12. Wreckage and Impact

The aircraft was not damaged except for the MLG tyres.

1.12.1. Aircraft Examination

The aircraft stopped with its nose landing gear (NLG) and right MLG rested on the grass area off the right-hand side of RWY 25R within the touchdown zone between TWY A3 and A4, approximately 250 m from the threshold of RWY 07L. The nose wheels had stopped approximately 2.1 m beyond the edge of the runway and had created two furrows, each approximately 21 m long. The MLG wheels had stopped approximately 6.7 m beyond the edge of the RWY 25R and ploughed two furrows, each approximately 32 m long.

1.12.2. Runway Inspection

Tyre tracks could be traced from the aircraft back along the runway indicating that the aircraft started to skid to the right side before reaching the 1 500 ft touchdown marking for RWY 07L.

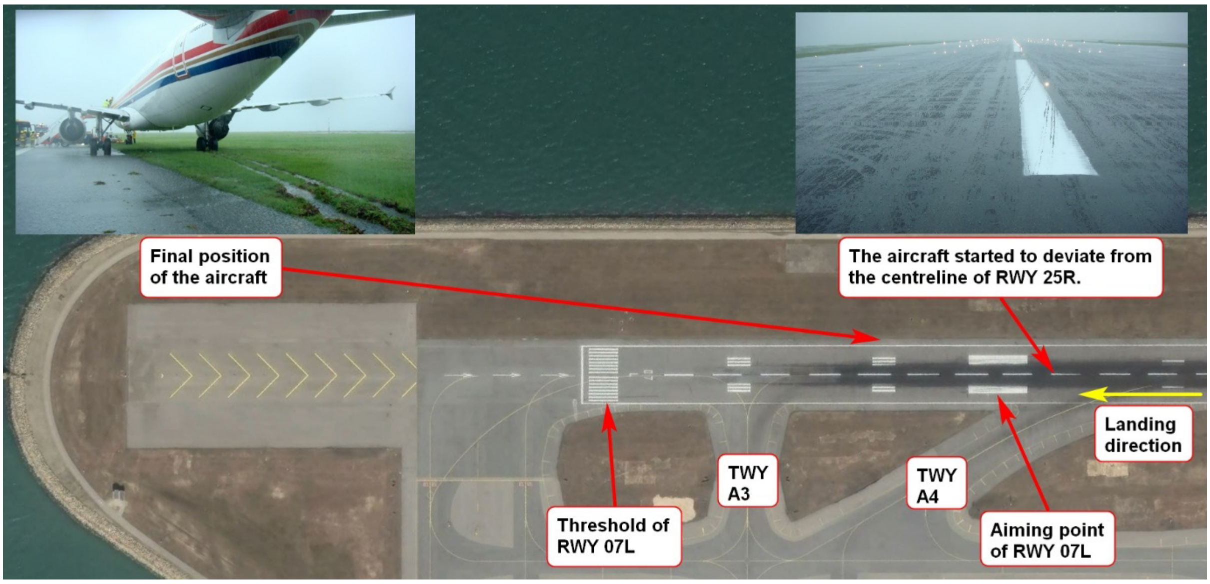

Figure 12: Aircraft Final Position

Photo 9: Aircraft Tyre Marks of Deviation from the Runway Centreline

Photo 10: Aircraft Tyre Marks

Photo 11: Steam-cleaned Mark Caused by the Tyres

1.13. Medical/Pathological Information

No medical or pathological investigations were conducted as a result of this occurrence.

1.14. Smoke, Fire, and Fumes

There was no smoke or fire on the aircraft after the incident.

1.15. Survival Aspects

(1) The Crash Alarm was activated by ATC immediately after the incident. AFC vehicles were on scene at 1052 hrs and it was later found that the situation appeared stable. There were no signs of fire, smoke or obvious structural damage.

(2) After communicating with the flight crew, AFC learnt that no passengers were injured. Disembarkation of passengers, which was assisted by AFC on scene, via a passenger steps vehicle commenced at 1133 hrs and was completed at 1201 hrs. Aircraft towing was initiated at 1222 hrs and the North Runway was reopened at 1243 hrs. The aircraft was eventually parked at Bay V131 at around the same time.

(3) Therefore, no investigations on the survival aspects were required.

Photo 12: Disembarkation of Passengers

1.16. Tests and Research

1.16.1. MLG Tyre Examination

Inspection of MLG tyres during the onsite investigation displayed evidence of damage associated with hydroplaning. All four main gear tyres were removed and forwarded to Michelin ROH CO., Ltd in Thailand for examination and evaluation.

1.17. Organisation, Management, System Safety

1.17.1. China Eastern Airlines Jiangsu Limited

China Eastern Airlines Jiangsu Limited is a joint venture of China Eastern Airlines Co., Ltd. and Jiangsu Province, China. The company was established on 7 April 1993, and completed a joint reorganization with Nanjing Airlines Co., Ltd. in 2004. The company operates a fleet of Airbus A319, A320 and A321 passenger aircraft. The Nanjing Lukou International Airport is its main base.

1.17.2. Airport Authority Hong Kong

(1) The AAHK is a statutory body established in 1995 with a mandate to operate and manage the HKIA. The AAHK is governed by the Airport Authority Ordinance.

(2) The aerodrome maintenance of HKIA including runway pavement was based on the Standards and Recommended Practices as per Annex 14 *Aerodromes* to the Convention on International Civil Aviation. AAHK is required to ensure the operations of HKIA comply with the safety and security requirements of CAD in order to obtain an Aerodrome Licence from CAD for operating the Airport.

1.17.3. Civil Aviation Department

The CAD of HKSAR Government is responsible for the provision of air traffic control services, certification of Hong Kong registered aircraft, monitoring of airlines on their compliance with bilateral Air Services Agreements, the regulation of general civil aviation activities and overseeing airport security and the safety of airport operations.

1.18. Additional Information

1.18.1. ICAO Requirements and Guidance on Runway Surface Conditions

1.18.1.1. Water on a Runway

According to ICAO Annex 14 Aerodromes Edition 7, Volume I Aerodrome Design and Operations, Chapter 2 Aerodrome Data Recommendations 2.9.5 to 2.9.7, it is recommended that an inspection be carried out to monitor water on the runway.

*"**Water on a runway***

2.9.5 Recommendation.— Whenever water is present on a runway, a description of the runway surface conditions should be made available using the following terms:

DAMP — the surface shows a change of colour due to moisture.

WET — the surface is soaked but there is no standing water.

STANDING WATER — for aeroplane performance purposes, a runway where more than 25 per cent of the runway surface area (whether in isolated areas or not) within the required length and width being used is covered by water more than 3 mm deep.

2.9.6 Information that a runway or portion thereof may be slippery when wet shall be made available.

Note.— The determination that a runway or portion thereof may be slippery when wet is not based solely on the friction measurement obtained using a continuous friction measuring device. Supplementary tools to undertake this assessment are described in the Airport Services Manual (Doc 9137), Part 2.

2.9.7 Notification shall be given to aerodrome users when the friction level of a paved runway or portion thereof is less than that specified by the State in accordance with 10.2.3.

Note.— Guidance on conducting a runway surface friction characteristics evaluation programme that includes determining and expressing the minimum friction level is provided in Attachment A, Section 7."

1.18.1.2. Monitoring of Runway Surface Conditions

(1) According to ICAO Doc 9137 *Airport Services Manual Part 2 Pavement Surface Conditions*, Chapter 1 1.3 *Need for Assessment of Runway*

Surface Conditions, runway surface friction/speed characteristics need to be determined under the following circumstances:

(a) *the wet runway case, where only periodical measurements of the runway surface friction characteristics are required to determine that they are above a maintenance planning level and/or minimum acceptable level. In this context, it is to be noted that serious reduction of friction coefficient in terms of viscous aquaplaning can result from contamination of the runway, when wet, by rubber deposits.*

(b) *the presence of a significant depth of water on the runway, in which case the need for determination of the aquaplaning tendency must be recognized.*

(c) *the slippery runway under unusual conditions, where additional measurements should be made when such conditions occur.*

(d) The above situations may require the following approaches on the part of the airport authority. For wet runway conditions, corrective maintenance action should be considered whenever the runway surface friction characteristics are below a maintenance planning level. If the runway surface friction characteristics are below a minimum acceptable friction level, corrective maintenance action must be taken, and in addition, information on the potential slipperiness of the runway when wet should be made available.

1.18.1.3. Friction Tests of Runway Surface

(1) According to ICAO Doc 9137 *Airport Services Manual Part 2 Pavement Surface Conditions,* Chapter 3 3.2 *Measurement*, friction tests of existing surface conditions should be taken periodically in order to identify runways with low friction when wet. A State should define what minimum friction level it considers acceptable before a runway is classified as slippery when wet and should publish this value in the State's AIP.

(2) When the friction of a runway or a portion thereof is found to be below this reported value, then such information should be promulgated by a NOTAM. The State should also establish a maintenance planning level, below which appropriate corrective maintenance should be considered to improve the friction. However, when the friction characteristics for either the entire runway or a portion thereof are below the minimum friction level, corrective maintenance action must be taken without delay.

1.18.2. Microtexture and Macrotexture of Runway Surface

(1) The microtexture and the macrotexture of runway surface are shown in the following figure.

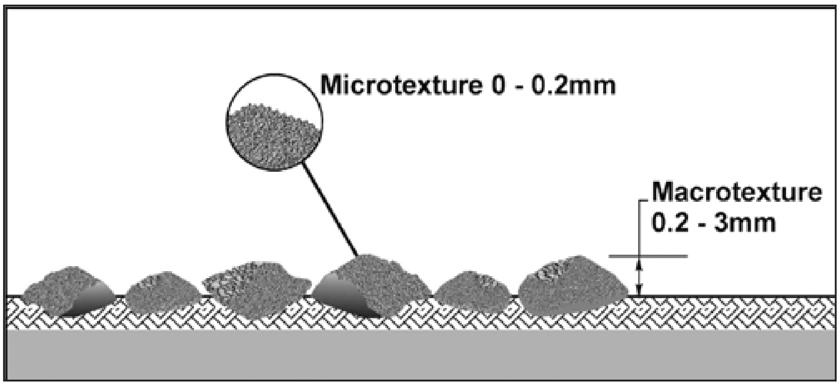

Figure 13: Runway Surface Microtexture and Macrotexture

(Source: Impact of Airport Rubber Removal Techniques on Runways – Airport Cooperative Research Program (ACRP) Synthesis 11, p.5 Figure 1)

(2) The following information is extracted from Annex 14 (Seventh Edition — July 2016 with Amendment 13-B) Attachment A Section 7.

"*7.3.4 Microtexture is the texture of the individual stones and is hardly detectable by the eye. Microtexture is considered a primary component in skid resistance at slow speeds. On a wet surface at higher speeds a water film may prevent direct contact between the surface asperities and the tire due to insufficient drainage from the tyre-to-ground contact area.*

7.3.5 Microtexture is a built-in quality of the pavement surface. By specifying crushed material that will withstand polishing microtexture, drainage of thin waterfilms are ensured for a longer period of time. Resistance against polishing is expressed in terms of the Polished Stone Values (PSV) which is in principle a value obtained from a friction measurement in accordance with international standards. These standards define the PSV minima that will enable a material with a good microtexture to be selected.

7.3.6 A major problem with microtexture is that it can change within short time periods without being easily detected. A typical example of this is the accumulation of rubber deposits in the touchdown area which will largely mask microtexture without necessarily reducing macrotexture.

7.3.7 Macrotexture is the texture among the individual stones. This scale of texture may be judged approximately by the eye. Macrotexture is primarily created by the size of aggregate used or by surface treatment of *the pavement and is the major factor influencing drainage capacity at high speeds. Materials shall be selected so as to achieve good macrotexture.*

7.3.8 The primary purpose of grooving a runway surface is to enhance surface drainage. Natural drainage can be slowed down by surface texture, but grooving can speed up the drainage by providing a shorter drainage path and increasing the drainage rate."

1.18.3. Grooving of Runways

(1) Grooving reduces the potential for both dynamic and viscous hydroplaning, by providing a place (i.e. grooves) for the water to escape from underneath tyres. Grooving is applied to both the microtexture and macrotexture of the runway surface.

(2) Annex 6 of the ICAO defines a grooved or porous friction course (PFC) runway as "a paved runway that has been prepared with lateral grooving or a porous friction course surface to improve braking characteristics when wet."

1.18.4. HKIA Runway Slope Gradients and Drainage

The maximum transverse slope is 1.5% for runways, 2.5% for shoulder, and 5% for runway strip. These values are in compliance with sections 3.1.19 *Transverse slopes*, 3.2.3 *Slopes on runway shoulders (Recommendation)*, and 3.4.15 *Transverse slopes* of Volume 1 *Aerodrome Design and Operations* of ICAO Annex 14. The purpose of the transverse slope is to facilitate the drainage of rainwater down to the landscape area. At the landscape area, most of the surface runoff from the runway can be dissipated by infiltration to the soil and the rest will be carried away through the gullies, underground drainage pipes and box culvert to the drainage outfall and finally to the sea.

1.18.5. Level of Runway Strip at HKIA

From photos 2, 11 and 12, it seemed that the level of the runway strip was higher than runway drainage. According to the information provided by AAHK, the soil or surface level of the strip was designed and constructed to be flush with the asphalt surface at the edge of the shoulder. In any event, the level of the strip was generally flush with the asphalt surface at the edge of shoulder. The presence of the grass made the strip look higher than the asphalt surface of the runway.

1.18.6. Hydroplaning

(1) Hydroplaning is caused by a layer of water beneath the tyre which builds up in increasing resistance to displacement and finally results in the formation of a wedge between the tyre and the runway surface. This

resistance has a vertical component which progressively lifts the tyre and reduces the area in contact with the runway, leading to a loss of traction and degrading both the braking and directional controllability of an aircraft, until the aircraft is completely water-borne.

(2) There are three types of hydroplaning: dynamic hydroplaning, viscous hydroplaning, and reverted rubber hydroplaning.

1.18.6.1. Dynamic Hydroplaning

(1) This is the phenomenon that is normally referred to as aquaplaning. It can occur when an aircraft lands fast enough on a sufficiently wet runway when the tyre is lifted off and completely supported by the water. It is typically associated with large water depths and runways having a very low macrotexture depth (less than 0.25 mm). These low macrotexture depths are very rare and large water depths can only occur during very heavy rain.

(2) The latest data from studies indicates that the estimated minimum speed (Vp in knot) of radial tyres for dynamic hydroplaning during landing is equal to $5.865\sqrt{P}$, where p is the tyre pressure in psi.

(3) For the tyre pressure of the incident aircraft, the minimum speeds are:

Main Gear		Nose Gear	
Pressure (psig)	Speed (kt)	Pressure (psig)	Speed (kt)
220-230	83-85	180	75

Table 12: Estimated Minimum Dynamic Hydroplaning Speeds

1.18.6.2. Viscous Hydroplaning

(1) Viscous hydroplaning occurs when a paved runway surface is wet and provides a very thin film of water which cannot be punctured by the tyre. Viscous hydroplaning can occur at water depths of less than 0.025 mm and at much lower speed than dynamic hydroplaning. It is particularly associated with a smooth or smooth-acting surface such as the touchdown zone where there is an excessive build-up of rubber deposits.

(2) Viscous hydroplaning does not need much water and could happen on a damp runway. There is a general misconception that a grooved runway will prevent viscous hydroplaning. Indeed, a good, sharp microtexture on the surface in between the grooves is needed to prevent it. The braking performance on wet grooved runways is worse than expected due to the smooth microtexture of the runway surface.

1.18.6.3. Reverted Rubber Hydroplaning

This type of hydroplaning can happen following dynamic or viscous hydroplaning. When an aircraft wheel on the wet runway surface locks during braking, the friction caused by the surface creates enough heat to turn the underlying water film into a cushion of steam. The pressure of the steam lifts the centre of the tyre off the surface leaving the edges still in contact creating a seal which traps the steam, which then melts the rubber. The tyre surface will have 'bubbled' rubber deposits on it. The runway will show distinctive marks in the form of being pressure washed as the tyre effectively 'steam cleans' it. Friction levels during this type of aquaplaning are the equivalent of icy runways.

1.18.7. Air Traffic Services

1.18.7.1. Runway Braking Action

(1) On the incident day from 1007 hrs to 1026 hrs, a total of six arrivals on RWY 07L carried out missed approaches due to windshear in the flare, low visibility and heavy rain. Since the surface wind was mainly northwesterly to northeasterly resulting in a crosswind condition for aircraft landing on either RWY 07L or RWY 25R, after consideration of the developing weather conditions in approach and landing on RWY 07L, ATC changed dual RWY 07 to dual RWY 25 in accordance with standard operating procedures.

(2) ATC received a braking action report from the third to last landing on RWY 07L stating that it was ‘poor’ at 1028 hrs. The penultimate landing was then on the same frequency and about to land on RWY 07L. ATC relayed the cautionary message to the last arrival flight on RWY 07L which landed uneventfully and managed to vacate the runway at TWY A7.

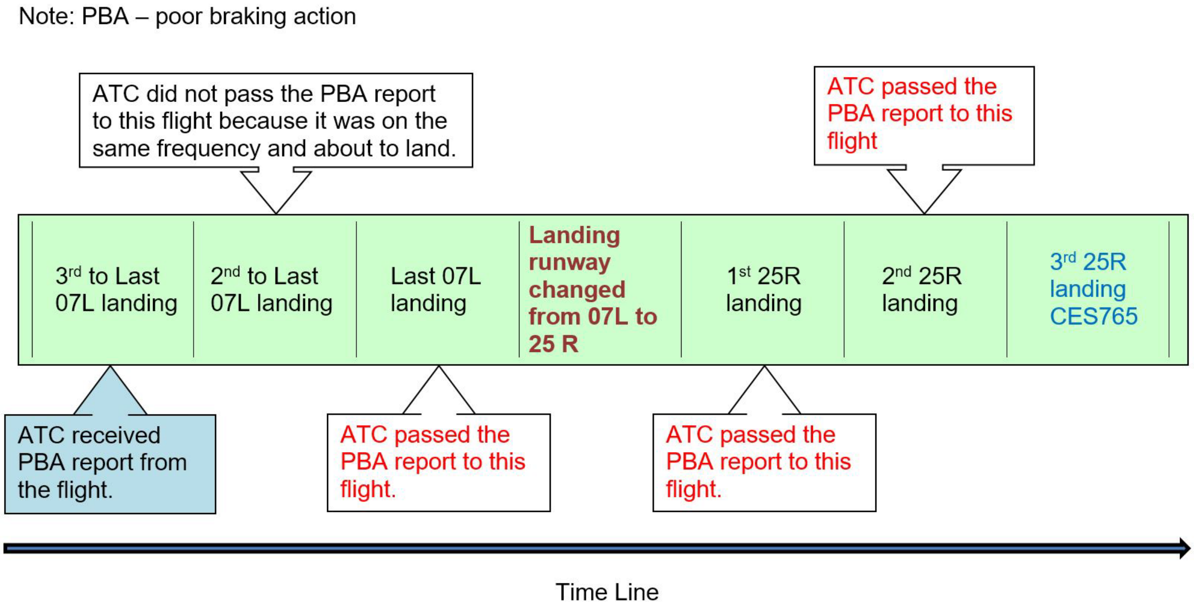

Figure 14: Pass-on of PBA Report

(3) After the change to RWY 25R for landing, CES765 was No.3 in the arrival sequence. ATC continued to pass the cautionary message "caution preceding traffic reported poor braking action on the runway" to the first and second landing aircraft on RWY 25R. Both aircraft did not comment on the poor braking action to ATC after landing. The second landing was an Airbus A320 and vacated RWY 25R via the first RET TWY A6. ATC discontinued the braking action warning and the cautionary message was subsequently discontinued and not passed to CES765.

1.18.7.2. Expedite Vacating Runway

CES765 did not vacate the runway at RET A6 or A5. To prepare for the next approaching arrival flight, ATC instructed CES765 to expedite vacating runway via RET A4 which the aircraft also missed. After informing the following arrival aircraft to continue the approach and expect a late landing clearance, ATC instructed CES765 to expedite vacating runway via TWY A3. Then the CES765 flight crew responded that the aircraft had skidded off the runway.

1.18.8. Global Reporting Format for Runway Surface Conditions[10]

(1) The International Civil Aviation Organisation (ICAO) introduced a new methodology for assessing and reporting runway surface conditions, commonly known as the Global Reporting Format (GRF) which became effective from 0000 UTC 4 November 2021. It enables the harmonized assessment and reporting of runway surface conditions and a

[10] ICAO Doc 9981 *Aerodromes* Third Edition, 2020

correspondingly improved flight crew assessment of take-off and landing performance.

(2) Standard runway condition report (RCR) is used for reporting assessed information on the runway surface conditions, whenever water, snow, slush, ice or frost are present on an operational runway. From this assessment and using a Runway Condition Assessment Matrix (RCAM), a runway condition code (RWYCC) (Appendix 10.3) and a description of the runway surface are reported. All other pertinent information will be taken into consideration and be kept up to date and changes in conditions reported without delay.

(3) The RWYCC reflects the runway braking capability as a function of the surface conditions. With this information, the flight crew can derive, from the performance information provided by the aeroplane manufacturer, the necessary stopping distance of an aircraft on the approach under the prevailing conditions.

1.19. Useful or Effective Investigation Techniques

Not applicable in this investigation.

2. Safety Analysis

The Safety Analysis provides a detailed discussion of the safety factors identified during the investigation, providing the evidence required to support the findings, contributing factors and the safety recommendations.

2.1. Introduction

(1) During the landing on RWY 25R at HKIA, the aircraft touched down on the runway centreline at a distance of approximately 764 ft beyond the 1 500 ft aiming point marking. The landing configuration, airspeed, and descent rate were normal. The autobrake mode selected was LO which was for a long and dry runway. There were no aircraft serviceability issues.

(2) This analysis will first discuss the meteorological conditions and the runway conditions. It will then discuss the flight operations and a range of other factors identified during the investigation.

2.2. Meteorological Conditions

2.2.1. Flight Crew's Observations

(1) In the interview, the crew of CES765 advised that they had initiated a missed approach at decision altitude during the first approach into RWY 07L due to heavy rain and low visibility. During the approach to RWY 25R, the weather radar showed clear areas within 3 nautical miles final of RWY 25R and the missed approach path. There was rain during the short final but it was not heavy. The rain was significantly less than that of the first approach, and was approximately light to medium at 1 000 ft altitude. The landing environment of RWY 25R could be clearly seen.

(2) The PF could not recall if the Data Link Automatic Terminal Information Service (D-ATIS) showed "wet" for the runway condition. The PM recalled that at the time of the aircraft veered off the runway was wet.

2.2.2. NOTAM and ATIS

The crew had already experienced a go around at decision altitude from RWY 07L due to heavy rain and poor visibility, they were radar vectored for a further approach during which time the landing runway was changed to the reciprocal RWY 25R. Although no NOTAM was issued prior to the incident notifying that the runway might be liable to be slippery when wet, ATIS 'B' and 'C' and SPECI VHHH issued at 1041 hrs indicated that RWY 25R was wet and would be subject to thunderstorm with heavy rain. The runway and weather conditions would have been apparent to the crew. Such information should be taken into account by the flight crew in the estimation of the landing distance.

2.2.3. Rainfall Records

In the morning of the day of incident, Hong Kong including the airport was affected by heavy or very heavy rain and thunderstorms. From 0915 hrs to 1130 hrs, the Red Rainstorm signal was issued by the HKO. It indicated that within this period heavy rain had fallen or was expected to fall generally over Hong Kong, exceeding 50 mm in an hour, and was likely to continue. It was highly probable that at least part of the surface of RWY 25R covered by the rollout of the aircraft was contaminated with water.

2.3. Runway Conditions

Starting from around 1006 hrs of the day, six arrival flights, including CES765, went around from RWY 07L due to windshear, fluctuating wind conditions and rain caused by a thunderstorm in the vicinity of HKIA. All flight crew of these arrival flights would have known the prevailing weather conditions at HKIA and that the runway surface was wet.

2.3.1. Water on the Runway

From photos 1, 2 and 8 to 12, it can be seen that the RWY 25R surface behind and in the vicinity of the last position of the aircraft was contaminated with water.

2.3.2. Notification of Low Runway Friction

(1) The results for the runway friction measurement from the Griptester on 21 May 2017 and 24 May 2017 indicated that the average friction values, 0.27 and 0.32 respectively, were below the limit (0.43) published in AIP HK (AD1.1-11 paragraph 16.1, dated 28 July 2011). However, CAD, including ATC and APSD, was not notified until the early afternoon of 24 May 2017. AAHK explained that the low runway surface friction measurement readings were considered abnormal. Instead of relying on friction measurement readings by the Griptester which was considered unreliable, AAHK carried out visual runway inspection surveys on both days in accordance with ICAO guidance and confirmed the runway pavement conditions was normal. For this reason, AAHK had not reported the abnormally low and hence unreliable runway friction values to CAD. As CAD was not notified, no NOTAM was issued to advise pilots that the runway could be slippery when wet.

(2) The Griptesters passed a health check and completed a full calibration conducted by AAHK's contractor in accordance with the Operations & Maintenance Manual on 22 May 2017, and there was no evidence of Griptesters malfunction before the friction measurement on 24 May 2017.

In addition, the measurement results of 24 May 2017 were basically consistent with those of 21 May 2017 as shown in Table 10, especially for runway portions between Chainage 301 and 700. The above points illustrate that it was probable that the measurements of the runway portions, which were below the limit of 0.43, reflected that the runway surface was liable to be slippery when wet on the incident day.

(3) Low runway friction may lead to potential undesirable consequences for aircraft during takeoff or landing. It is therefore essential to notify pilots by means of NOTAM or ATIS so that flight crew may assess the implication in a timely manner. If AAHK considered the low measurements from the Griptester being abnormal, all values measured by the Griptester should be treated as unreliable. They should have immediately reported those abnormality to CAD, who would promulgate the information as appropriate. After that, AAHK should review the values and take timely follow-up actions, if necessary, to restore the friction to an acceptable level.

2.3.3. Crosswind Effect on Drainage

The incident aircraft landed with a crosswind from the right. Crosswinds may prevent adequate runway drainage of water, causing pooling. A runway surface with a coarse matrix or grooves takes longer time for water to build up to limiting depths, particularly in windy conditions. Under zero wind conditions most runways have adequate crossfall to provide good drainage under quite high rates of precipitation. However, drainage can be seriously affected in wind of about 10 kt or above. A crosswind blowing up the transverse slope of a runway could have a significant effect on water depth. This could lead to hydroplaning on that side and hence asymmetric braking action.

2.4. Flight Operations

Selected flight data related to the landing rollout is presented in Appendix 10.2. Some of the plots are extracted and inserted in the paragraphs below with additional annotations.

2.4.1. Autobrake Mode for Landing

From the ATIS and the flight crew’s observation during the go around on RWY 07L and the approach to RWY 25R, they should have been aware that the runway was not dry. Selecting the MED autobrake mode therefore should be more appropriate. However, the flight crew selected the LO autobrake mode which was for long and dry runway.

2.4.2. Landing Rollout

2.4.2.1. Touchdown Position

The aircraft landed on the runway centreline at a point about 2 264 ft beyond the RWY 25R threshold, i.e. 764 ft beyond the normal touchdown target area of 1 000 ft to 1 500 ft from the threshold. Consequently, the aircraft had less runway distance to decelerate and was closer to the touchdown zone of the opposite runway which was commonly known to have more rubber deposits.

2.4.2.2. Touchdown and Rollout with Autobrake

The aircraft touched down at 10:49:47 hrs at an airspeed of 148 kt. During de-rotation onto the nose wheel, the thrust levers were first brought to IDLE and then maximum reverser thrust. The ground spoilers extended automatically and the LO autobrake mode was activated. The aircraft heading was maintained on the runway with rudder inputs and the ground speed decreased to 90 kt at 10:50:06 hrs when the aircraft was at point B (see Figure 11) in a duration of 19 seconds. The average longitudinal deceleration was about 0.16 G which was close to the target deceleration rate (0.17 G).

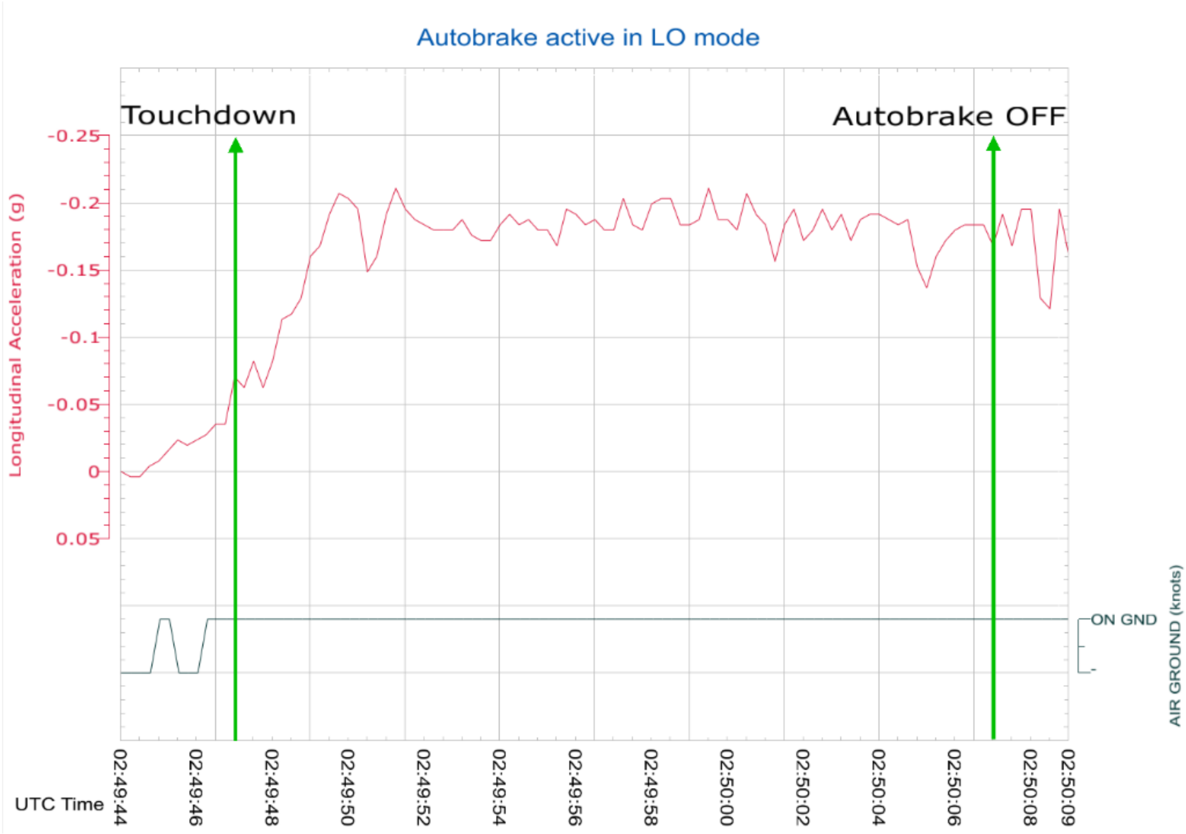

Figure 15: Aircraft Deceleration from Touchdown to Autobrake Off

2.4.3. Reaction to Slow Deceleration

(1) At 10:50:06 hrs, the aircraft was at a ground speed of 90 kt at point B, the PF pressed on the brake pedals and this action disengaged the autobrake. The aircraft at this stage was still under normal braking with antiskid.

(2) The deceleration was around 0.2 G with a peak of 0.28 G in the following 10 seconds. At about point C, the deceleration then decreased to about 0.02 G when no brake pedal input was noted during the next four seconds (from 10:50:18 hrs to 10:50:22 hrs, from point D to point E). Brake pedal inputs were then noted at 10:50:21 hrs with a progressive increase to maximum at 10:50:30 hrs. However, the deceleration remained at around 0.05 G. It was highly probable that the aircraft was experiencing viscous hydroplaning. The aircraft heading was still maintained at around 253 degrees with rudder inputs. The ground speed decreased from 90 kt to 42 kt at 10:50:36 hrs at point F with both thrust levers put to FWD IDLE.

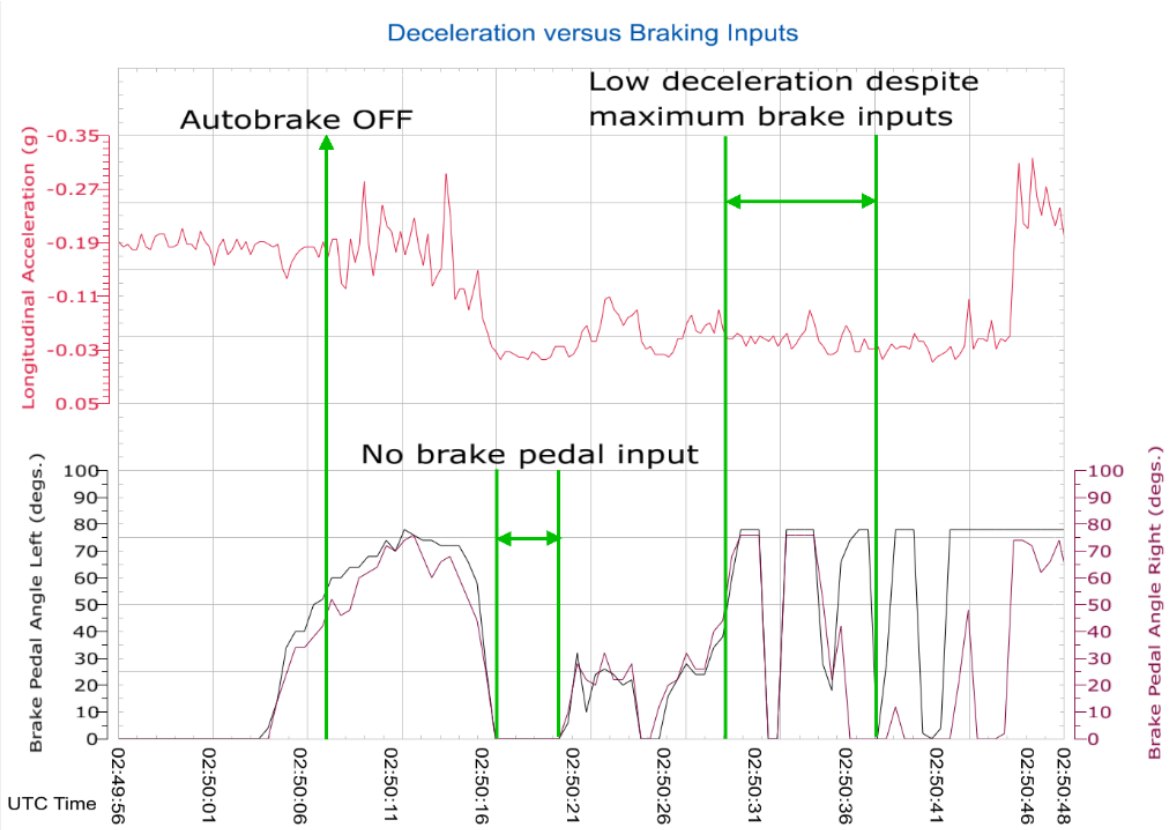

Figure 16: Deceleration versus Brake Pedal Inputs in Normal Manual Braking

(3) At 10:50:17 hrs the PF moved both thrust levers to FWD IDLE at 70 kt in accordance with the FCOM. However, at this moment the aircraft was just short of point D which was near the entrance of TWY A5, only 3 575 ft from the threshold of the opposite runway. Since the braking action was not effective, appropriate reverse thrust as a means of stopping should have been held until the landing rollout could be contained comfortably within the

distance available, but both thrust levers were left at the FWD IDLE position (see Figure 26 in Appendix 10.2) until the aircraft rolled past point F.

(4) At 10:50:36 hrs, the aircraft decelerated to 42 kt at point F near the entrance of TWY A4. This location was within the section of runway, identified as Chainage 300 to 700 for runway friction measurement and rubber removal purposes (see Figure 11), and with average friction values below the limit then published in AIP HK. At this point, the flight crew turned off the antiskid.

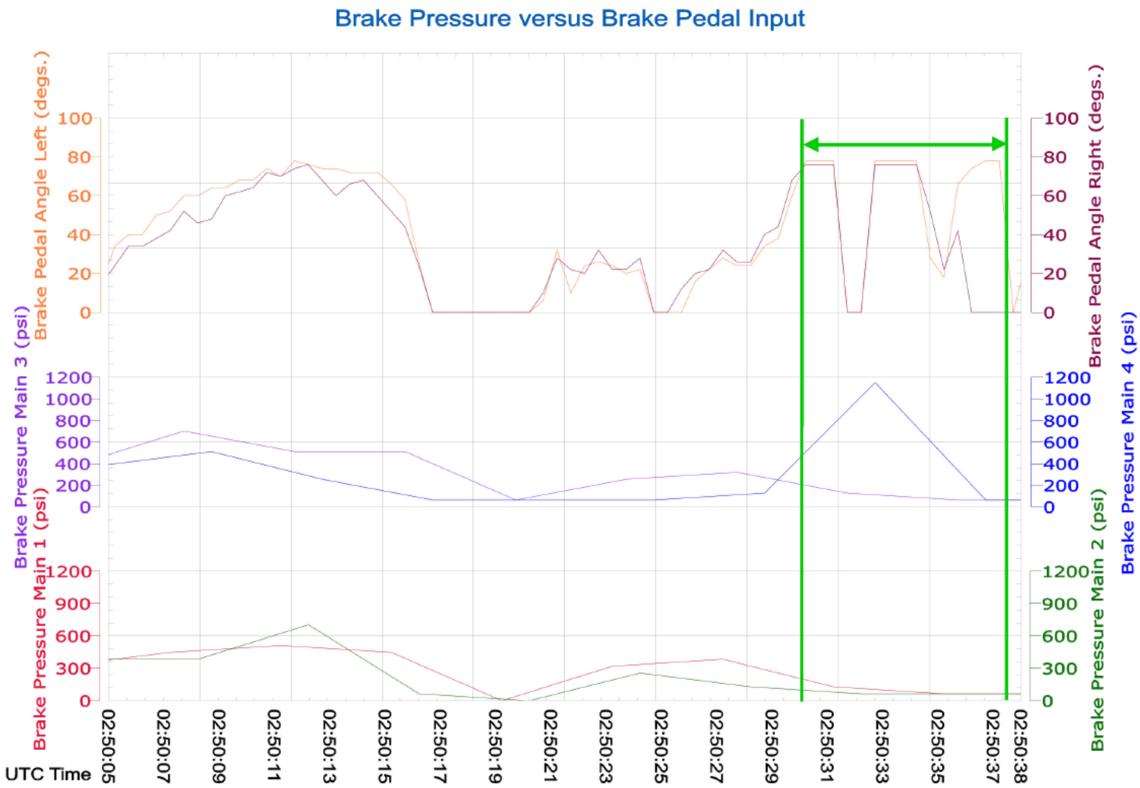

Figure 17: Brake Pressure versus Pedal Inputs in Normal Manual Braking

(5) The figure above revealed that the brake pressure followed the pedal inputs until about 10:50:30 hrs. From this point on, the brake pressure remained low even though full brake pedal inputs were made. This indicated that the antiskid system was operating by reducing brake pressure to prevent the wheels from locking, which implied that the runway was contaminated with water. The runway section travelled by the aircraft between 10:50:31 hrs and 10:50:38 hrs pretty much aligned with the Chainage range with below average runway friction values.

2.4.3.1. Loss of Braking Procedures

(1) At 10:50:36 hrs, the aircraft was at point F. As the required deceleration rate was not achieved, the flight crew applied the Loss of Braking procedures in the QRH to set the A/SKID & N/W STRG switch to OFF.

The aircraft heading increased from 254 degrees and the deceleration was about 0.05 G only.

(2) When the antiskid was selected to OFF, Nose Wheel Steering control and hence directional control could only be effected by differential braking. The maximum braking pressure was also limited to 1 000 psi, which was 1 537 psi less than that in the normal manual braking mode.

(3) According to the flight data, there was no malfunction of the hydraulic system, brake system or the antiskid system. The application of the Loss of Braking procedures limited the use of maximum brake pressure, and cancelled the directional control with the tillers and aircraft wheel lockup protection with the antiskid system.

(4) Although the flight crew applied the Loss of Braking procedures and pressed on the brake pedals, they did not apply MAX reverse thrust which was the first step of the Loss of Braking procedures. According to the FCOM, if needed, flight crew can use maximum reverse thrust until the aircraft comes to a complete stop.

(5) The aircraft was then in a situation of decelerating by manual brake pedal inputs with limited brake pressure and without antiskid on a section of runway with below average friction values.

2.4.4. Heading Change and Lateral Deviation

(1) Starting from about 10:50:36 hrs, the aircraft heading continued to increase towards 268 degrees despite full left brake pedal inputs. The FDR data showed that differential braking was applied with maximum left pedal inputs which resulted in maximum rudder deflection. At the same time, it was noted that both No. 1 and No. 2 wheel speeds dropped from 40 kt to 0 kt while No. 3 and 4 wheel speeds were around 40 kt. This means that the left MLG wheels were locked and skidding occurred after differential braking to the left was applied. The aircraft still continued its deviation to the right. The deceleration did not improve and was still at about 0.05 G with ground speed at about 40 kt.

(2) Between 10:50:43 hrs and 10:50:45 hrs, the left-hand engine thrust lever was momentarily moved to the full forward throttle position and then retarded to the IDLE position. The right-hand engine thrust lever was then moved to half of the forward thrust position and was retarded to the IDLE position. By doing so, the flight crew was probably in an attempt to re-align the nose of the aircraft with the centreline of the runway. However, no appreciable effect on the aircraft heading was noted.

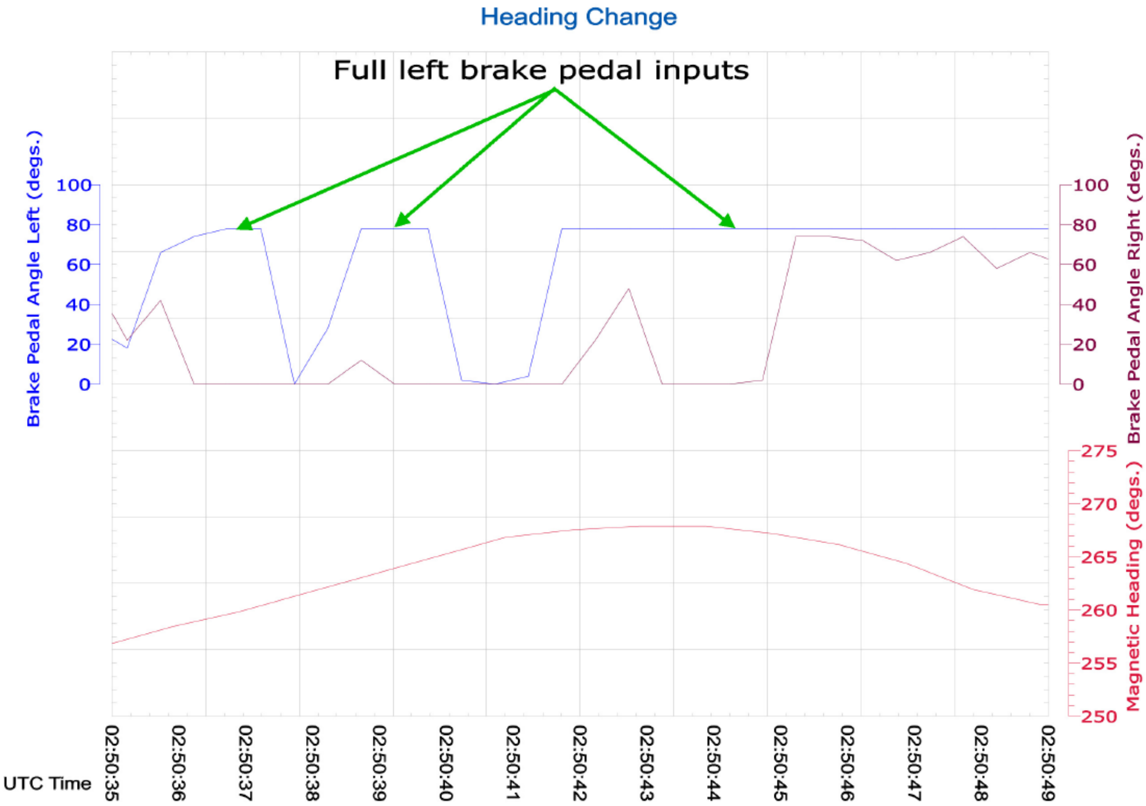

Figure 18: Aircraft Heading and Brake Pedal Inputs

2.4.5. Runway Excursion

(1) Between 10:50:46 hrs and 10:50:55 hrs, the aircraft heading changed to 254 degrees with the deceleration increased to about 0.3 G with a transient up to 0.45 G, probably because the aircraft exited the runway and rolled on the grass verge. The aircraft eventually stopped on the right side of the runway in the touchdown zone of RWY 07L.

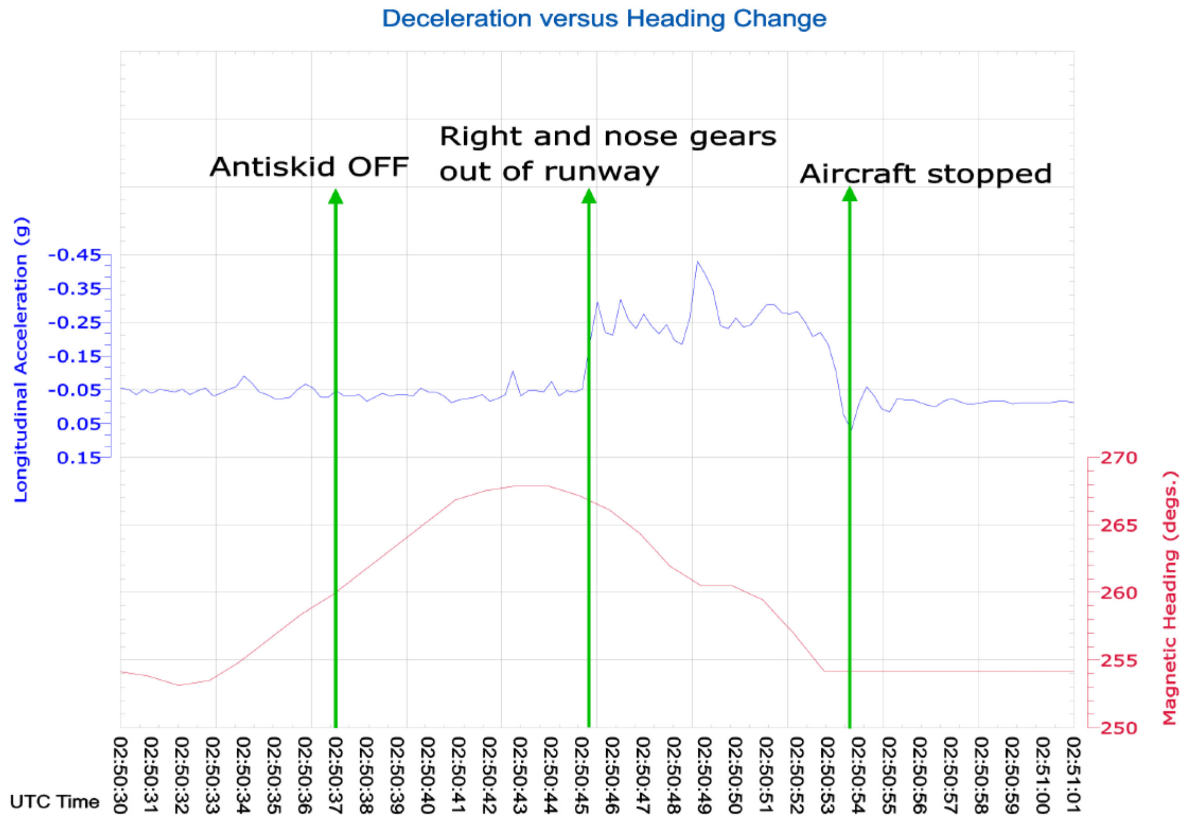

Figure 19: Deceleration versus Aircraft Heading - Antiskid OFF to Aircraft Stop

(2) The above figure indicated that the aircraft heading started to change at 10:50:33 hrs. The FDR data showed that the ground speed was 42 kt.

(3) Since the aircraft landed with a crosswind from the right, a weathercock effect[11] might be induced resulting in the aircraft turning to the right despite differential braking to the left was applied. It was highly probable that the lateral deviation to the right was a consequence of the weathercock effect combined with water contamination at the runway portions between Chainage 301 to 700 and friction values probably below the limit.

2.4.5.1. Analysis of the BSCU Data

(1) Fault codes 851 to 853 (corresponding to tachometers of the No.2 to No.4 wheels respectively) were recorded in the BSCU and the data was retrieved after the incident. The results of the analysis by Airbus indicated that the BSCU detected a large difference between the aircraft speed (higher than 15 m/s (29 kt)) and the speed of the affected wheels (lower than 5 m/s (9.7 kt)).

[11] Weathercocking is a phenomenon experienced by aircraft on the ground under crosswind condition. An aircraft has a greater profile or side area behind the main landing gears than forward of them. With the main wheels acting as a pivot point and the greater surface area exposed to the crosswind behind that pivot point, the aircraft tends to turn or "weathercock" into the wind.

(2) The BSCU data in combination of the FDR data supported the finding that the wheels locked up due to manual braking (almost full pedals inputs with maximum 1 000 psi in the brakes) in the Alternate Braking mode without antiskid under wet or contaminated runway conditions and the No. 3 and No.4 wheels were running in the grass verge.

2.4.6. Handling of the Rollout

(1) The first section of the rollout (point A to point B) had autobrake activated and the aircraft achieved a nominal deceleration of around 0.16 G in the LO autobrake mode. Its ground speed dropped to 90 kt correspondingly. Had the MED autobrake mode with a nominal deceleration rate of 0.3 G been selected before touchdown, given the same initial speed (148 kt) and the time duration (19 seconds), by calculation the aircraft speed would have been reduced to 39 kt at point B, which was before the entrance of TWY A6. This speed would have allowed the aircraft to enter RET A6 or RET A5 and vacate the runway. Indeed the arrival aircraft immediately preceding the incident aircraft was an A320 and was able to vacate the runway via RET A6.

(2) Normally, A320 series aircraft landing on RWY 25R are able to vacate the runway at either RET A6 or RET A5. It was unusual that an A320 series aircraft landing on RWY 25R would still be at a ground speed of 90 kt when it was at point B. With both thrust levers set to FWD IDLE at 70 kt, the deceleration relied only on the spoilers and the brakes. The deceleration rate started to drop at point C. Although some full brake inputs were applied, the deceleration rate remained very low. Had the full manual braking and the maximum reverse thrust been applied immediately starting from point B, the incident aircraft could have decelerated more effectively to a speed appropriate for vacating the runway at TWY A5. Indeed, on wet or contaminated runways the reverse thrust is likely to be more effective than the brakes.

(3) Before reaching point F, the flight crew applied the Loss of Braking procedures in reaction to the ineffective aircraft deceleration and set the A/SKID & N/W STRG to OFF at point F, when there was no malfunction of the hydraulic system, brake system and the antiskid system, and normal Green system hydraulic pressure and reverse thrust were available. This action undermined the available potential for deceleration and directional control of the aircraft.

2.5. Air Traffic Services

2.5.1. Runway Braking Action

(1) ATC received a report of poor braking action from the third to last arrival landed at 1028 hrs on RWY 07L. Considering the next (penultimate)

landing on RWY 07L was already on short final and only a few seconds from touching down, ATC exercised discretion and decided not to pass the cautionary message to the penultimate landing lest it might distract the pilot's attention. The aircraft landed uneventfully. ATC later passed the poor braking action cautionary information to the last landing on RWY 07L, and also to the first and second RWY 25R arrival flights.

(2) The abovementioned three arrivals that were given the cautionary message did not experience difficulty in vacating the runway and did not comment on the poor braking action. The second arrival on RWY 25R was able to exit the runway via the first RET A6. Both the first and second RWY 25R arrivals were Airbus A320 aircraft that have similar performance as CES765 which was the third arrival in sequence. Considering all the above factors, ATC did not further convey the cautionary message to CES765.

2.5.2. Expedite Vacating Runway

(1) On noting that CES765 missed RETs A6 and A5, ATC gave an "expedite vacating runway" instruction to CES765 because the following approaching arrival was getting close. If CES765 could vacate the runway via RET A4 in time, landing clearance would be available to the following arrival. Playback of radio transmission recordings between ATC and the flight crew indicated that ATC was visually monitoring the reaction of CES765 while transmitting to the following arrival.

(2) The ATC instruction of "expedite vacating runway" might have instilled a sense of urgency into the CES765 flight crew who might then get a feeling of time pressure. However, it is not an uncommon ATC operational practice in handling landing traffic. Except in emergency situations, the "expedite" instruction should translate to "as quick as you can commensurate with safety" with the sole purpose of maintaining a smooth air traffic flow.

(3) There will be occasions when pilots are unable to follow ATC instructions. For instance, on a wet runway different aircraft may perform differently and some may be slower in vacating. Good and professional communication skills should address this issue. On flight deck side, pilots unable to follow ATC instructions should clearly state their problem to ATC which in turn would choose other options. On the ATC side, understanding that pilots may not always be able to follow given instructions, ATC should always have an alternative and be prepared for any exigency under such circumstances. As seen in this incident, ATC instructed the following arrival to go around when it was known that the runway would not be available.

2.6. Engineering

2.6.1. Aircraft Maintenance

A review of the aircraft maintenance history did not identify any defects or recent maintenance actions that could contribute to the incident. The flight data analysis also did not highlight any aircraft system malfunction during the entire flight.

2.6.2. MLG Tyres Damage Assessment

(1) The tyres were examined by the manufacturer at their facilities in Thailand. The circumference of all the tyres was divided into 12 equal sectors for identification purpose. Figures 20 to 24 are excerpts from the manufacturer's report.

(2) On the No.1 tyre, a single hydroplane skid burn and rubber reversion were found on the tread (see Figure 20). There were also heavy chevron cutting on the centre tread rib around most of the circumference and some of the cutting were deep. On the tread rubber, heavy abrasion, significant scuffing and longitudinal scratches, which were probably caused by the skidding action when the aircraft veered off the runway, were identified.

(3) The No.2 tyre worn on the centre and the shoulder of the tread. Similar single hydroplane skid burn and rubber reversion were found on the tread (see Figure 21). Sign of heavy braking and a pattern of abrasion were found on the tread centre in one of the sectors (see Figure 22). There were heavy chevron cutting on the centre tread rib around the most of the circumference. Heavy abrasion and significant scuffing with longitudinal scratches were also found on the tread rubber.

(4) The damage on the No.3 tyre and the No.4 tyre was similar. The tread of two tyres showed a pattern of abrasion, and signs of less obvious rubber reversion, heavy abrasion, significant scuffing with longitudinal scratches, and heavy braking (see Figures 23 and 24). There was heavy chevron cutting on the centre tread rib around the most of the circumference. The chevron cutting in some areas was deep. Damage was found on both sides of the sidewall but did not extend to the casing plies. The damage was probably caused by foreign objects in the grass area.

Figure 20: Damage on No.1 Tyre

Figure 21: Damage on No.2 Tyre

Figure 22: Damage on No.2 Tyre (Cont'd)

Figure 23: Damage on No.3 Tyre

Figure 24: Damage on No.4 tyre

2.6.3. Hydroplaning

(1) Had dynamic hydroplaning occurred during the rollout, it should have occurred between point A (touchdown) and just beyond point B. It is because only the ground speeds of the incident aircraft within this distance would have fallen into the range of the minimum dynamic hydroplaning speeds as specified in paragraph 1.18.6.1. However, the FDR data showed that the aircraft deceleration between point A and point B matched the nominal value of the LO autobrake mode. Therefore, it is considered that no dynamic hydroplaning occurred in the rollout.

(2) In contrast, between point B and point G despite considerable manual braking, with or without antiskid, the braking performance stayed low as the aircraft was only decelerating at values between 0.05 G and 0.1 G. It indicated that viscous hydroplaning had occurred.

(3) Examination of the left MLG tyres revealed evidence of rubber reversion. The "steam-cleaned" marking (shown in Photo 11) was also found on the runway near the final stop position of the aircraft. They indicated that rubber reversion hydroplaning had also occurred between point F and point G probably following the viscous hydroplaning occurred prior to point F, and after the left MLG wheels were locked up due to full left pedal inputs.

2.7. Human Factors

2.7.1. Situational Awareness and Decision Making

2.7.1.1. Runway Conditions before Landing

When CES765 first attempted to land on RWY 07L, there was heavy rain caused by a thunderstorm in the vicinity of HKIA. However, during the approach to land on RWY 25R, the weather radar showed clear areas within 3 nautical miles final of RWY 25R and along the missed approach path. The rain observed by the flight crew during the short final was not heavy and the landing environment could be clearly seen. The flight crew might have misinterpreted all the information as a significant improvement of the weather conditions and expected the runway was not wet despite ATIS 'C' indicated runway surface wet, which led them to choose the LO autobrake mode. As discussed in paragraphs 2.4.1 and 2.4.6, the MED autobrake mode would be the appropriate one to use in that situation.

2.7.1.2. Controlling Aircraft Speed during Rollout

(1) At point B, the aircraft was still travelling at a speed of 90 kt instead of around 35 kt to 45 kt that would allow the aircraft to vacate the runway via RET A6. The flight crew then had to re-assess this situation together with other information such as the aircraft location, runway surface conditions, speed trend, braking performance, no braking related system malfunction

and the remaining runway distance. They also had to compare the re-assessment results with the goal of vacating the runway via RETs A5 and A4. The maximum deceleration potentials they could make use of were the full manual braking with antiskid and the maximum reverse thrust.

(2) The aircraft travelled from point B to point F in about 30 seconds. During the period, other than some maximum manual braking being applied within the first 12 seconds, no combination of maximum manual braking and maximum reverse thrust was applied. The thrust levers were moved to FWD IDLE at 70 kt in accordance with the FCOM.

(3) It was possible that during rollout the flight crew might not have had the appropriate mental models to anticipate the outcome of the braking effect and modify their actions to achieve the goal. In general, the building and updating of mental models can be achieved through better understanding of the situations, appropriate training and gaining more experience.

2.8. Global Reporting Format for Runway Surface Conditions

(1) According to Flight Safety Foundation, ineffective braking action, due to runway contamination such as snow, ice, slush or water, is the third most common landing excursion risk factor. Shortfalls in the accuracy and timeliness of runway assessment and reporting methods by aerodromes have contributed to the problem. Although friction measurement equipment is useful for runway maintenance purposes, the measurement results may not correlate with actual aircraft performance and hence are misleading to pilots.

(2) The Global Reporting Format for Runway Surface Conditions helps mitigate the risk of excursion due to ineffective braking action. The GRF enables runway surface conditions (the outcome of the assessment and associated RWYCC) to be reported in a standardized Runway Condition Report (RCR), such that flight crew can accurately determine aircraft take-off and landing performance by correlating the code with performance data provided by their aircraft's manufacturer. The GRF also incorporates the potential to communicate actual runway surface conditions to flight crew in real time and in terms that directly relate to aircraft performance data. The GRF can be used in all climates and provides a means for aerodrome operators to correctly assess runway surface conditions including rapidly changing conditions such as those experienced during winter or in tropical climates.

(3) CAD published Aeronautical Information Circular (AIC) 29 / 21 *Implementation of ICAO Global Reporting Format (GRF) for Runway Surface Conditions at Hong Kong International Airport (HKIA)* on 7 October 2021. It describes the collection, dissemination and use of information on runway surface conditions at HKIA.

3. Conclusions

3.1. Findings

(1) The aircraft veered off to the right of the runway and stopped at the grass verge abeam a point between TWYs A4 and A3. [1.1 (3)]

(2) The flight crew members were licensed and qualified for the flight in accordance with existing regulations. [1.5.1 (1)]

(3) The maintenance records indicated that the aircraft was equipped and maintained in accordance with existing regulations and approved procedures. (1.6.2)

(4) The aircraft was airworthy when dispatched for the flight. There was no evidence of the aircraft having experienced a technical fault. [1.6.1 (2), 1.6.2 and 1.6.3]

(5) The antiskid and brake system operated as designed. (1.6.7)

(6) The meteorological information indicated that the RED rainstorm warning was effective at the time the incident aircraft landed at 10:49:47 hrs. A total of 40.9 mm of rain was recorded at the airport in the 60 minutes prior to the incident. [1.1 (2) and 1.7 (2)]

(7) The ATIS Arrival information 'C' at 1041 hrs advised that the runway surface was wet and there would be thunderstorms with heavy rain. [1.7 (6)]

(8) The friction measurement values measured by the Griptester of the runway surface between point E and the 500ft marking of the RWY 07L touchdown zone were below the AIP HK published limit on the incident day. Such friction measurement values were considered abnormal by AAHK as presented by a malfunctioned equipment and therefore in accordance with the ICAO's guidance mentioned in paragraph 1.10.4(6), AAHK conducted a visual inspection survey of the runway surface by professional engineering staff which confirmed the runway was safe for operation. (1.10.4 and 1.10.5)

(9) Runway friction measurement using the Griptester was carried out on 21 May 2017 and 24 May 2017, and the average values between Chainage 101 and Chainage 800 were below the limit of 0.43 published in AIP HK AD1.1-11 paragraph 16.1 dated 28 July 2011. As AAHK considered that the low friction values were abnormal which AAHK believed was resulted from an equipment malfunction and the visual inspection surveys conducted in accordance with ICAO's guidance shortly afterwards by AAHK confirmed that the North Runway surface condition was normal and safe,

CAD was not notified of the friction measurement results and therefore no NOTAM was issued to alert flight crew that the runway could be slippery when wet (1.10.5 and 1.10.6)

(10) The aircraft touched down on the runway centreline at a distance 764 ft beyond the 1 500 ft aiming point marking. (2.1)

(11) It was probable that the measurements of North Runway portions between Chainage 301 and 700 were below the limit of 0.43 on the incident day. [2.3.2 (2)]

(12) The longitudinal deceleration between touchdown (point A) and point B of the rollout was about 0.16 G which was close to the target deceleration rate of the LO autobrake mode. The aircraft ground speed reduced to 90 kt at point B. (2.4.2.2)

(13) The deceleration of the aircraft was not effective between point B and point F. Despite some significant manual brake pedal inputs, the aircraft still travelled at 42 kt at point F. [2.4.3 (2), (3) and (4)]

(14) At 10:50:17 hrs the PF moved both thrust levers to FWD IDLE at 70 kt in accordance with the FCOM. [2.4.3 (3)]

(15) The flight crew applied the Loss of Braking Abnormal and Emergency Procedures before point F and switched off the antiskid and nose wheel steering at point F. The directional control was down to differential braking and was not effective. Maximum reverse thrust could have been applied in accordance with the procedures but was not selected. (2.4.3.1)

(16) It was highly probable that the lateral deviation to the right was a consequence of the weathercock effect combined with water contamination at the runway portions between Chainage 301 to 700 and friction values probably below the limit. [2.3.2 (2) and 2.4.5 (3)]

(17) Had autobrake in the MED mode been selected, by calculation the aircraft speed would have dropped to 39 kt at point B and the aircraft would have been able to exit the runway through RET A6 or RET A5. [2.4.6 (1)]

(18) ATC received report of poor braking action from the third to last arrival landed on RWY 07L at 1028 hrs. The poor braking action cautionary information was passed to the last landing on RWY 07L, and also to the first and second RWY 25R arrival flights. All the above three arrivals did not observe difficulty in vacating the runway and did not comment on the poor braking action. The second RWY 25R arrival, an A320, was able to exit the runway by the first RET A6. The subject A321 was the third in sequence for an ILS approach to RWY 25R with similar aircraft performance of preceding two landings on the same runway. Considering

all the above factors, ATC did not further convey the cautionary information to CES765. (2.5.1)

(19) The ATC instruction of “expedite vacating runway” on noting that CES765 missed RETs A6 and A5 might have instilled a sense of urgency into the CES765 flight crew who might then get a feeling of time pressure. However, it is not an uncommon ATC operational practice in handling landing traffic. [2.5.2 (1) and (2)]

(20) The results of tyre examination indicated that the No.1 and No.2 tyres showed signs of rubber reversion, heavy abrasion, significant scuffing and longitudinal scratches. The No.3 and No.4 tyres did not have significant signs of rubber reversion but suffered from sidewall damage which was probably caused by foreign objects on the grass area. (2.6.2)

(21) No dynamic hydroplaning occurred in the rollout. [2.6.3 (1)]

(22) Viscous hydroplaning occurred between point B and point G of the rollout. [2.6.3 (2)]

(23) Steam-cleaned marks were observed on the runway in the vicinity of the veer-off point. [2.6.3 (3)]

(24) The flight crew selected the LO autobrake mode, which is for long and dry runway, for landing. The MED autobrake mode should be the appropriate one to use in this landing rollout. (2.7.1.1)

(25) It was possible that the flight crew might not have had the appropriate mental models to anticipate the outcome of the braking effect and modify their actions to achieve the goal of deceleration. [2.7.1.2 (3)]

3.2. Causes

(1) The flight crew considered that the runway was dry and selected the inappropriate autobrake mode before landing. Their subsequent aircraft speed control after the aircraft missed RET A6 was also ineffective to decelerate the aircraft to a speed appropriate for vacating the runway via RET A5 or RET A4. [3.1 (13) and (24)]

(2) At the last stage of the rollout, the weathercock effect created by the lateral wind turned the aircraft to the right and the directional control by differential braking was not effective on the runway section which was contaminated with water and with friction values probably below the limit. [3.1 (15) and (16)]

3.3. Contributing Factors

(1) The aircraft landed long and touched down at a distance 764 ft beyond the 1 500 ft aiming point marking, resulting in reduced time and distance to decelerate. [3.1 (10)]

(2) After the deceleration rate was found unsatisfactory upon point B, the flight crew did not make the best use of manual braking and reverse thrust to slow the aircraft down to the desired speed. [3.1 (13), (14) and (15)]

(3) The aircraft suffered viscous hydroplaning between point B and point G of the rollout, which resulted in poor braking action and reduced aircraft deceleration rate. [3.1 (22)]

4. Safety Actions Already Implemented

Whether or not the AAIA identifies safety issues in the course of an investigation, relevant organisations may proactively initiate safety action in order to reduce their risks.

The AAIA has been advised of the following proactive safety action in response to this occurrence.

4.1. Safety Actions Already Implemented

4.1.1. CAD

After the incident, CAD held a number of meetings with AAHK between May and July 2017 and both parties agreed on a clearer and more comprehensive reporting and response mechanism regarding runway friction measurement. A tabulated reporting and response mechanism has been incorporated into AAHK Aerodrome Manual Part 8 Appendix 8C, whereby runway zone-specific friction measurements and the associated reporting and response measures for abnormal friction values have been set out in details. Should abnormal friction values be obtained from the measurements, CAD would be informed in a timely manner.

4.1.2. AAHK

More refined work planning and inspection procedures were developed and were briefly described below.

4.1.2.1. Future Runway Resurfacing Programme Planning

The non-grooved area would be limited in the entire resurfacing programme and the grooving of the resurfaced pavement would be completed before the wet season. Before commencement of the resurfacing programme, NOTAM / AIC would be issued to notify flight crew and airline operators on the change of runway conditions.

4.1.2.2. Refinement of Runway Surface Friction Measurement Procedure

(1) An enhanced response action plan was implemented from 1 August 2017 by AAHK. Whenever the friction values do not meet the required levels as stipulated in ICAO Doc 9137 Airport Services Manual Part 2 Pavement Surface Conditions, AAHK would alert CAD, including ATC and APSD immediately. In addition, the frequency of friction measurements for both the North Runway and the South Runway was increased to a weekly basis with effect from the same date.

(2) Furthermore, a more modern Surface Friction Tester Vehicle (SFTV) was procured by AAHK in July 2017 and commissioned in March 2018. The second SFTV was procured in March 2019 and commissioned in April 2019.

4.1.2.3. Strengthening Rubber Removal Capacity

(1) A new rubber removal machine was procured and commissioned in August 2017 to enhance the rubber removal capacity.

(2) With effect from 1 August 2017, the rubber removal programme was revised as follows:

TDZ	OCT - MAR	APR - SEP
North Runway 07L	Once per month	Once per two months
North Runway 25R	Once every three months	Once per two months
South Runway 07R	Once every two months	Once per two months
South Runway 25L	Once every three months	Once per two months

Table 13: AAHK Rubber Removal Capacity Enhancement

4.1.3. ATC

(1) Three days after the occurrence of this incident, a standing instruction had been issued to Tower controllers requiring them to obtain two braking action reports per hour from pilots whenever a runway is wet. If the reported braking action is less than "good", the cautionary information will be included in ATIS and passed on to the Approach Control or the Final Director so that arriving flights can be forewarned as appropriate. In addition, Tower controllers should consider requesting bigger landing spacing. The Tower Supervisor will also follow up with AAHK. The standing instruction had been incorporated in the Manual of Air Traffic Control (MATC) in February 2021.

(2) AIC 29 / 21 *Implementation of ICAO Global Reporting Format (GRF) for Runway Surface Conditions at Hong Kong International Airport (HKIA)* had been issued on 7 October 2021 for the implementation of enhanced Global Reporting Format for assessing and reporting runway surface conditions in the ICAO Procedures for Air Traffic Management (Doc 4444 PANS-ATM, Amendment 7B, Section 4.12.7), which became effective on 4 November 2021. Internal standing instruction of the enhanced Global Reporting Format procedures was issued on 15 October 2021 and the MATC would be amended in due course.

5. Safety Recommendations

5.1. Safety Recommendation 10-2022

It is recommended that China Eastern Jiangsu Airways reviews and enhances flight crew training on landing in severe weather conditions, so that the flight crew can establish appropriate mental models in handling the situations. [3.1 (25)]

Safety Recommendation Owner: China Eastern Jiangsu Airways

6. Implementation of Safety Recommendations

(1) China Eastern Airlines (the parent company of China Eastern Jiangsu Airways) proactively implemented the following safety actions which addressed the Safety Recommendation made. After review by the AAIA the Safety Recommendation is considered closed.

(a) The Flight Standard and Training Department published guidance materials in Flight Operations Information Bulletin (FOIB) CEA-FOIB-2017-05 *Operational Notice on Avoidance of Runway Excursion and Veer-Off during Approach and Landing in Precipitation Conditions* and pilot training were arranged to update their knowledge on this subject. The issue was also brought up to the management as one of the top ten company risks.

(b) The Flight Standard and Training Department published guidance materials in FOIB A320-2017-04[12] *Information Circular on Brake Failure Procedures and Functions of Antiskid and Nosewheel Steering ON/OFF Switch on Airbus Models* to enhance pilots' knowledge and distributed it to all pilots.

(c) The Flight Standard and Training Department published guidance materials in FOIB-2017-07R1 *Technical Information Circular of Prevention of Runway Excursion and Veer-off for Airbus Models* on landing on wet runway with strong crosswind to enhance pilots' knowledge and distributed it to all pilots.

(d) The Flight Standard and Training Department established training courses on Operation on Contaminated Runway, Approach in Critical Weather, Braking Operation, and Reverser Operation for all pilots. The above training information and the related landing skills enhancement were also incorporated in the annual Computer-based Training (CBT) and the simulator training.

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[12] This FOIB was also incorporated in FOIB-2017-07R1 *Technical Information Circular of Prevention of Runway Excursion and Veer-off for Airbus Models* as Appendix 6.

7. General Details

7.1. Occurrence Details

Date and time:	24 May 2017, 0251 hrs UTC (1051 hrs Hong Kong local time)	
Occurrence category:	Serious Incident	
Primary occurrence type:	RE: Runway excursion	
Location:	Runway 25R, Hong Kong International Airport, Hong Kong	
	Latitude: 22°18'41.14"N	Longitude: 113°53'58.32"E

7.2. Personnel Information

7.2.1. Pilot-in-Command

Age:	30 years
Licence:	Civil Aviation Administration of China, Airline Transport Pilot License, valid until 11 February 2021
Aircraft ratings:	A-320; Single-Engine Land; Multi-engine Land
Date of first issue of aircraft rating on type:	22 November 2011
Instrument rating:	Instrument-Airplane
Medical certificate:	Class I Medical Certificate, valid until 15 August 2017
Date of last proficiency check on type:	18 May 2017
Date of last line check on type:	11 May 2017
Date of last emergency drills check:	16 September 2016

ICAO Language Proficiency:	English Language Proficiency Level 4 valid until 1 November 2019
Limitation:	Nil
Flying Experience:	
Total all types:	5 981 hours
Total on type (A319/320/321) :	5 731 hours
Total in last 90 days:	237 hours
Total in last 30 days :	80 hours
Total in last 7 days:	19 hours
Total in last 24 hours:	2.8 hours
Duty Time:	
Day up to the incident flight (Hours:Mins) :	2 hours 49 minutes
Day prior to incident (Hours:Mins) :	0 hours 0 minutes

7.2.2. First Officer

Age:	31 years
Licence:	Civil Aviation Administration of China, Commercial Pilot License, valid until 27 October 2022
Aircraft ratings:	A-320 (Co-Pilot Only); Single-Engine Land; Multiengine Land
Date of first issue of aircraft rating on type:	22 July 2011
Instrument rating:	Instrument-Airplane
Medical certificate:	Class I Medical Certificate, valid until 17 August 2017
Date of last proficiency check on type:	10 May 2017

Date of last line check on type:	Nil
Date of last emergency drills check:	4 November 2015
ICAO Language Proficiency:	English Language Proficiency Level 4 valid until 27 July 2020
Limitation:	Nil
Flying Experience:	
Total all types:	4 594 hours
Total on type (A319/320/321) :	3 300 hours
Total in last 90 days:	208 hours
Total in last 30 days :	70 hours
Total in last 7 days:	2.8 hours
Total in last 24 hours:	2.8 hours
Duty Time:	
Day up to the incident flight (Hours:Mins) :	2 hours 49 minutes
Day prior to incident (Hours:Mins) :	0 hours 0 minutes

7.3. Aircraft Details

Manufacturer and Model:	Airbus A321-211	
Registration:	China, B-6366	
Aircraft Serial Number:	3593	
Flight Number:	CES765	
Year of Manufacture:	2008	
Engine:	Two CFM International CFM56-5B3 turbo-fan engines	
Operator:	China Eastern Airlines Jiangsu Limited (中国东方航空江苏有限公司)	
Type of Operation:	Commercial Air Transport (Passenger)	
Certificate of Airworthiness:	Transport Category (Passenger) issued on 28 July 2008, valid until 31 December 2017	
Departure:	Nanjing Lukou International Airport (ZSNJ)	
Destination:	Hong Kong International Airport (VHHH)	
Maximum Take-off Weight:	93 000 kg	
Total Airframe Hours:	27 871.8	
Total Airframe Cycles:	15 656	
Persons on board:	Crew – 9	Passengers – 132
Injuries:	Crew – 0	Passengers – 0
Aircraft damage:	Minor Damage on Tyres	

7.4. Aerodrome Information

7.4.1. Aerodrome of Destination

Aerodrome Code:	VHHH
Airport Name:	Hong Kong International Airport
Airport Address:	Chek Lap Kok, Lantau Island
Airport Authority:	Airport Authority Hong Kong
Air Navigation Services:	Approach Control, Aerodrome Control, Ground Movement Control, Zone Control, Flight Information Service, Clearance Delivery Control, Automatic Terminal Information Service
Type of Traffic Permitted:	IFR/VFR
Coordinates:	22° 18' 32" N, 113° 54' 53" E
Elevation:	28 ft
Runway Length:	3,800 m
Runway Width:	60 m
Stopway:	Nil
Runway End Safety Area:	240 m x 150 m
Azimuth:	07L / 25R, 07R / 25L
Category for Rescue and Fire Fighting Services:	CAT 10

8. Abbreviations

A/SKID	Antiskid
AAHK	Airport Authority Hong Kong
ABCU	Alternate Brake Control Unit
ADIRU	Air Data Inertia Reference Unit
AFC	Airport Fire Contingent
AGL	Above Ground Level
AIC	Aeronautical Information Circular
AIP	Aeronautical Information Publication
AIP HK	Aeronautical Information Publication of Hong Kong.
AMO	Airport Meteorological Office
APSD	Airport Standards Division of Civil Aviation Department
ASDA	Accelerated stop distance available
ATC	Air Traffic Control
ATIS	Automatic Terminal Information Service
BRK	Brake
BSCU	Brake and Steering Control Unit
CAD	Civil Aviation Department
CAT	Category
CBR	California Bearing Ratio
CBT	Computer-based Training
CES	ICAO Code of China Eastern Airlines Co., Ltd
CVR	Cockpit Voice Recorder
DRS	Digital Recording System
FCOM	Flight Crew Operating Manual
FDR	Flight Data Recorder

ft	Feet
FWD IDLE	Forward Idle Thrust
GRF	Global Reporting Format
HKIA	Hong Kong International Airport
HKO	Hong Kong Observatory
hrs	hours
ICAO	International Civil Aviation Organization
IFR	Instrument flight rules
ILS	Instrument Landing System
kg	Kilogram(s)
km	Kilometre(s)
kt	Knot(s)
LDA	Landing distance available
LO	Low
LT	Local Time
m	Metre(s)
MAX	Maximum
MED	Medium
METAR	Meteorological Report
MLG	Main Landing Gear
mm	Millimetre(s)
N/W	Nose Wheel
NOTAM	Notice To Airmen
PCN	Pavement Classification Number
PF	Pilot Flying
PFC	Porous Friction Course

PIC	Pilot in command
PM	Pilot Monitoring
PR	Pressure
psi	Pound per square inch
PSV	Polished Stone Values
QRH	Quick Reference Handbook
RCAM	Runway Condition Assessment Matrix
RCR	Runway condition report
RE	Runway Excursion
RET	Rapid Exit Taxiway
REV IDLE	Reverse Idle Thrust
REV MAX	Reverse Maximum Thrust
RVR	Runway Visual Range
RWY	Runway
RWYCC	Runway condition code
SPECI	Special Meteorological Report
STRG	Steering
TODA	Take-off distance available
TORA	Take-off run available
TWY	Taxiway
UTC	Coordinated Universal Time
VFR	Visual flight rules
VHHH	ICAO code of Hong Kong International Airport
WTWS	Wind Shear and Turbulence Warning System
ZSNJ	ICAO code of Nanjing Lukou International Airport

9. Table of Figures, Photos, Tables

10. Appendix

10.1. Weather Radar Pictures

The location of the airport is highlighted by a red oval.

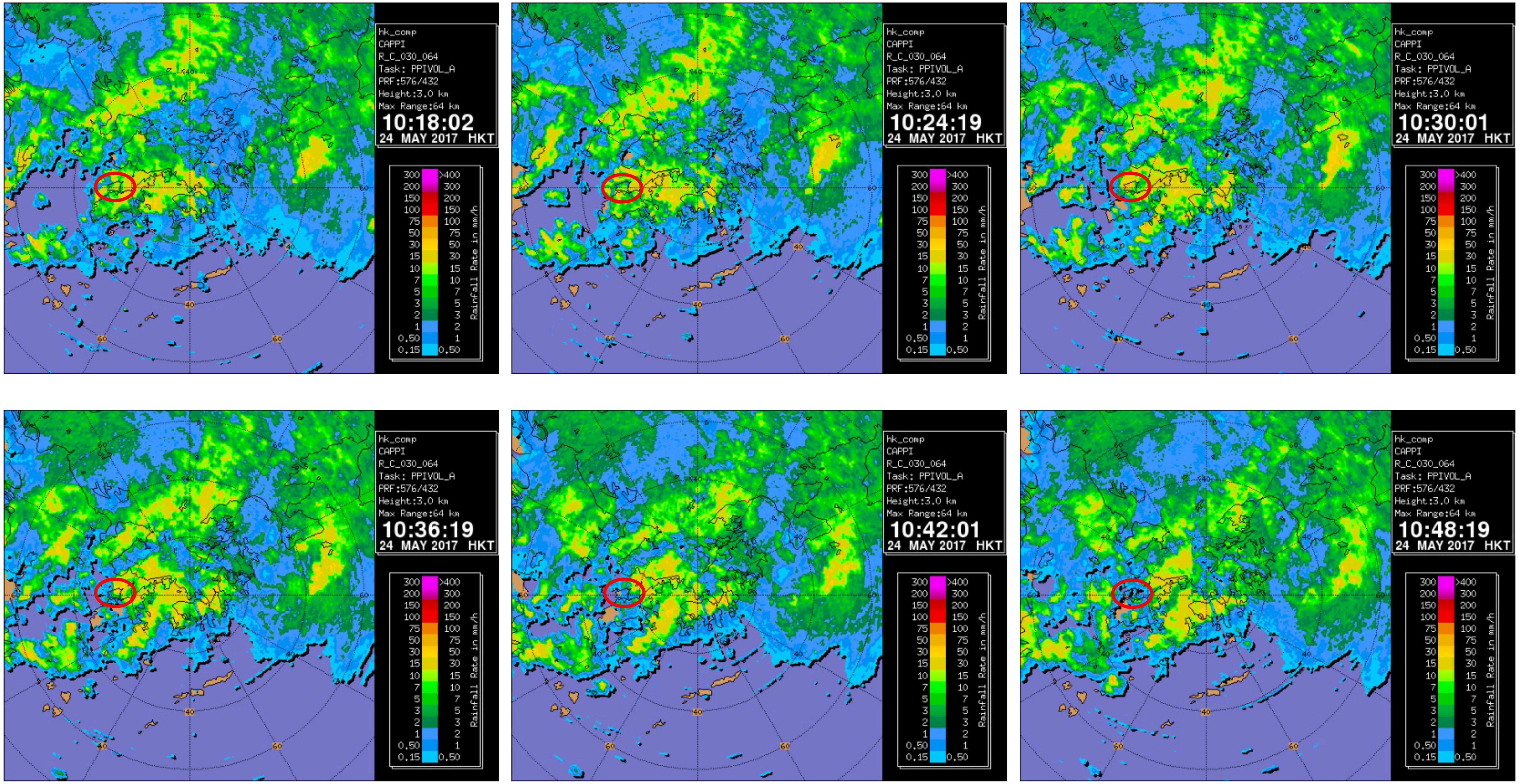

Figure 25: Weather Radar Pictures from 1018 to 1048 hrs Local Time

10.2. Selected Flight Data Related to Deceleration

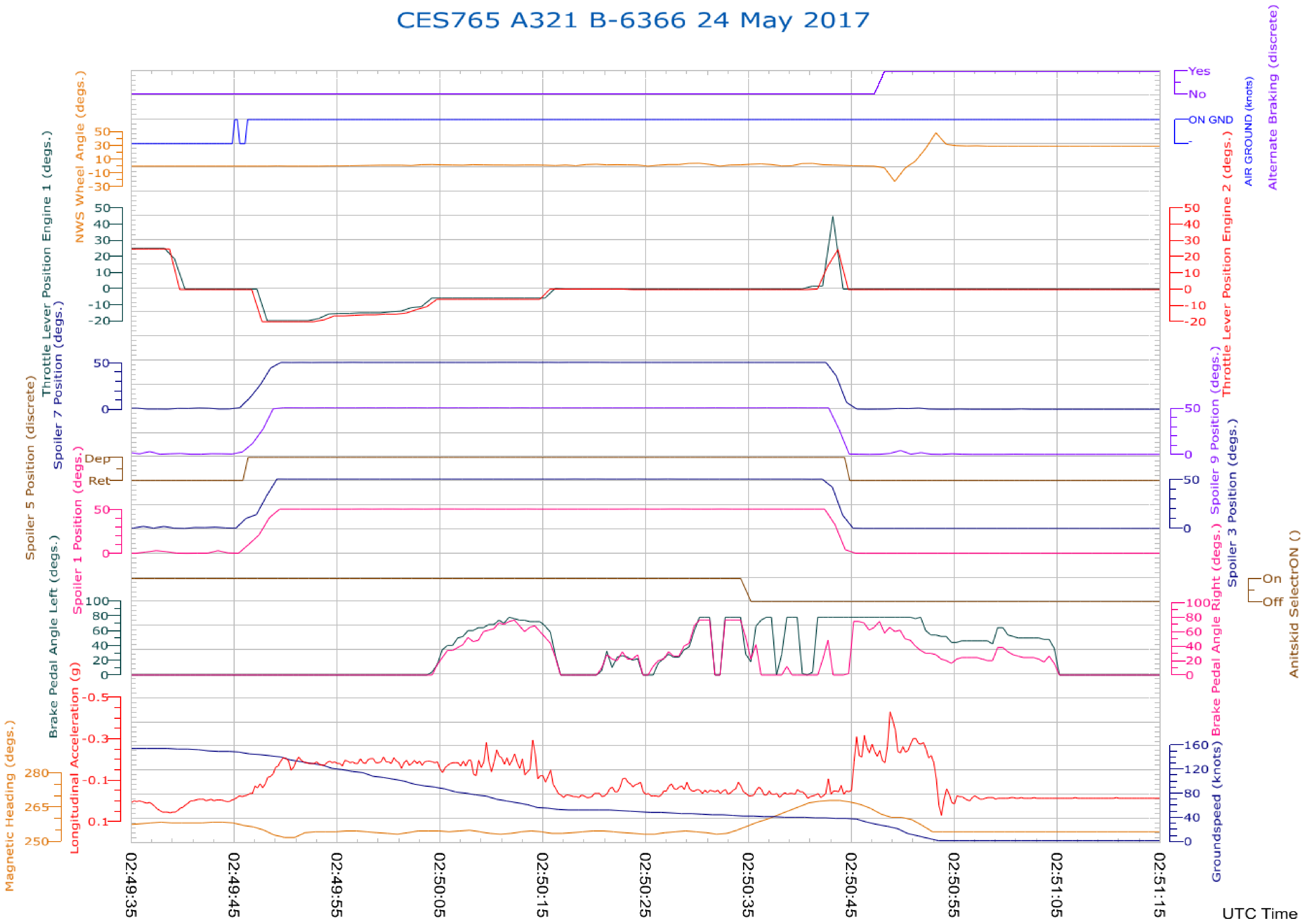

Figure 26: Selected Flight Data Related to Deceleration

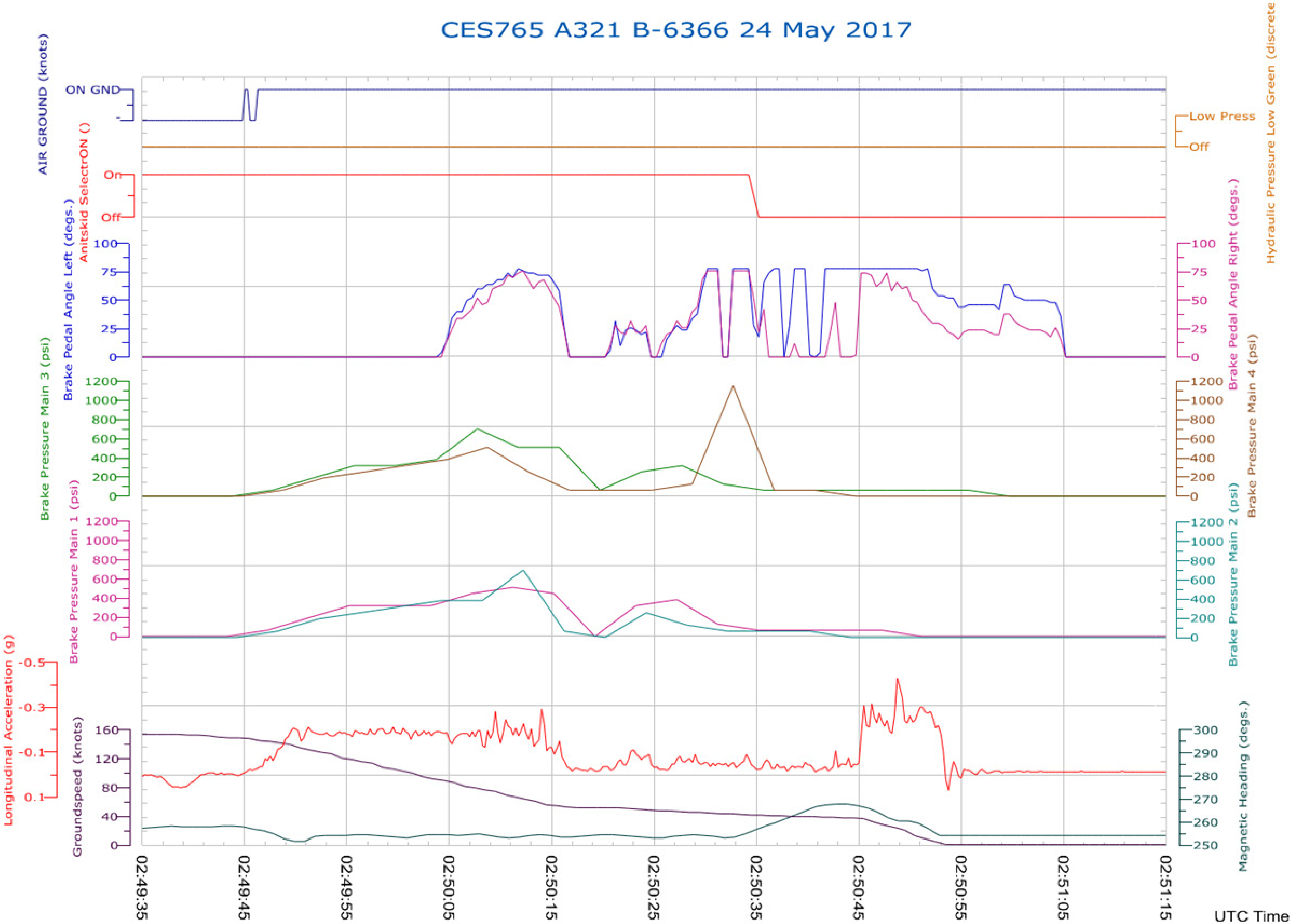

Figure 27: Selected Flight Data Related to Deceleration (Cont'd)

10.3. ICAO Runway Condition Code

Table II-2-3. Assigning a runway condition code (RWYCC)

Runway condition description	*Runway condition code (RWYCC)*
DRY	**6**
FROST **WET** (the runway surface is covered by any visible dampness or water up to and including 3 mm deep) **SLUSH** (up to and including 3 mm depth) **DRY SNOW** (up to and including 3 mm depth) **WET SNOW** (up to and including 3 mm depth)	**5**
COMPACTED SNOW (Outside air temperature minus 15 degrees Celsius and below)	**4**
WET ("Slippery wet" runway) **DRY SNOW** (more than 3 mm depth) **WET SNOW** (more than 3 mm depth) **DRY SNOW ON TOP OF COMPACTED SNOW** (any depth) **WET SNOW ON TOP OF COMPACTED SNOW** (any depth) **COMPACTED SNOW** (outside air temperature above minus 15 degrees Celsius)	**3**
STANDING WATER (more than 3 mm depth) **SLUSH** (more than 3 mm depth)	**2**
ICE	**1**
WET ICE **WATER ON TOP OF COMPACTED SNOW** **DRY SNOW OR WET SNOW ON TOP OF ICE**	**0**

(ICAO Doc 9981 Aerodromes Third Edition, 2020)

Figure 28: ICAO Runway Condition Code