Havarikommissionen
Accident Investigation Board Denmark

Final Report
HCLJ510-2012-172

Serious incident to Airbus A319-131
Registration OY-KBR
At Copenhagen Airport, Kastrup (Denmark)
On 21 November 2012

Table of contents

FINAL REPORT

HCLJ510-2012-172	**Serious incident**		
Aircraft:	Airbus A319-131	Registration:	OY-KBR
Engines:	2 – IAE V2522-A5	Flight:	Scheduled, IFR
Crew:	5 – No injuries	Passengers:	79 – No injuries
Place:	Copenhagen Airport, Kastrup (EKCH)	Date / time:	21.11.2012 at 07:38 UTC

The Aviation Unit of the Danish Accident Investigation Board (AIB-DK) was notified of the serious incident by the Area Control Centre at Copenhagen Airport, Kastrup on 21.11.2012 at 07:45 UTC.

The International Civil Aviation Organization (ICAO), the European Aviation Safety Agency (EASA) and the Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile (BEA) which is the French authority responsible for safety investigations were notified on 21.11.2012.

FACTUAL INFORMATION

History of the flight

The serious incident flight was a scheduled international passenger flight from Oslo Airport (ENGM) in Norway to Copenhagen Airport, Kastrup (EKCH) in Denmark.

The flight from Gardermoen to Copenhagen was uneventful.

The commander (CMD) was the flying pilot and landed the aircraft on runway (RWY) 22L. The aircraft rolled approximately 1.200 meters down the RWY before it vacated RWY 22L via taxiway (TWY) B4.

At the end of the straight part of TWY B4, the CMD was not able to keep the aircraft on the centerline of the curved end of TWY B4. The nose wheel was skidding on the asphalt and the aircraft left TWY B4 and went into the grass area southwest of the taxiway.

The aircraft came to rest in the grass area between TWY B4 and TWY B pointing in a westerly direction.

The auxiliary power unit was started and a normal shut down of the engines was performed by the cockpit crew.

The airport fire and rescue services arrived at the scene and secured the aircraft.

No one on board the aircraft was injured.

The crew and the passengers were transported to the airport terminal. At the terminal, the passengers were offered a debriefing. Nine passengers were debriefed by the CMD.

The serious incident took place in daylight under visual meteorological conditions (VMC).

Personnel information

The commander (CMD) – male – 57 years old was the holder of a valid Airline Transport Pilot License (ATPL) issued by the Danish Transport Authority on 26th February, 2001.

The following ratings were valid:

- DC9/MD-80/88/90
- A320 family
- IR (A) ME

The medical certificate class 1 was valid until 1st October 2013.

Flying hours:

Latest:	24 hours	90 days	Total
All aircraft types:	2	92	13460
This type:	2	76	76

A320 family type rating training:

Period:	Subject:
29.8.2012 – 16.9.2012	Technical training
17.9.2012 – 14.10.2012	Flight Simulator and procedures training
15.10.2012 – 3.11.2012	Instructed en-route flight training

After the type rating training was completed on 3rd of November 2012, the CMD was released and rated as commander on the A320 family.

The CMD flew 44 hours from 4th of November 2012 until the serious incident flight on 21th December 2012.

36 of the 44 hours were flown on routes that were longer than approx. 4 hrs.

The first officer (FO) was the holder of a valid Airline Transport Pilot License (ATPL) and was rated as commander on the A320 and the MD-80 series aircraft.

The FO was an experienced A320 series pilot.

Aircraft information

General

The Airbus A320 family consists of short- to medium-range, narrow-body, commercial passenger jet airliners manufactured by Airbus. The family includes the A318, A319, A320 and A321.

The aircraft was an A319 Serial number 3231 which is a shortened version of the A320.
The aircraft was delivered to the airline on 20th August, 2007.

Last renewal of the Airworthiness Review Certificate was on 14th August 2012.

MTOM: 66.000 kg.

The mass at the time of the serious incident: Approximately 51.000 kg.

The aircraft was within the mass and balance limitations at the time of the serious incident.

Wheel brake system

The main wheels were equipped with multidisc carbon brakes.

Carbon brake material is characterized by high temperature stability, high thermal conductivity, and high specific heat.
Carbon brake wear is primarily dependent on the total number of brake applications. One firm brake application causes less wear than several light applications. Maximum carbon brake durability can be achieved during taxi by using a small number of long, moderately firm brake applications instead of numerous light brake applications.

Carbon brake wear is much less sensitive to airplane weight and speed than steel brake wear.

The brake temperature was measured from all four brakes (two on each main landing gear) and was displayed on the Electronic Centralized Aircraft Monitor (ECAM) in the cockpit.

The brake temperature was displayed in green when the temperature was below 100° C. The green arc on the ECAM appears on the hottest wheel when one brake temperature exceeds 100° C. When the corresponding brake temperature exceeds 300° C the green arc becomes amber, and an ECAM caution appears.

Brake cooling fans were optional equipment. Brake cooling fans were not installed on the aircraft.

Nose wheel steering

Nose wheel steering hand wheels are located on the cockpit side consoles.
The steering hand wheels, which are interconnected, can steer the nose wheel up to 75° in either direction. A scale on the steering hand wheels indicates the relative position of the nose wheel.
There is no feedback to the steering hand wheel.

Operating procedures
There was no taxi speed limitation in the Flight Crew Operating Manual (FCOM) or Airplane Flight Manual (AFM).

The FCOM standard operating procedures contained the following sentence concerning – Taxi (out): (GS is an abbreviation of ground speed).

"BRAKES……..…..CHECK

- *Once the aircraft starts moving:*

Etc.

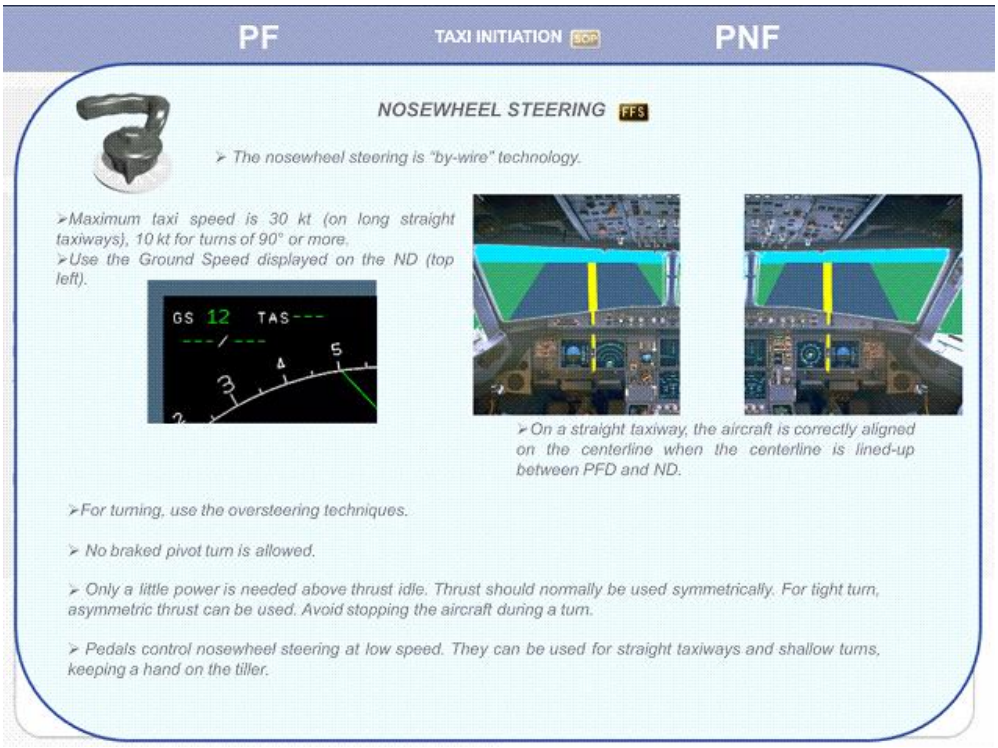
- *Thereafter the normal maximum taxi speed should be 30 knots in a straight line, 10 knots for a sharp turn. As the ground speed is difficult to assess, monitor ground speed on ND. Do not "ride" the brakes. As 30 knots is exceeded with idle thrust, apply brakes smoothly and decelerate to 10 knots, release the brakes and allow the aircraft to accelerate again."*

The A320 family Flight Crew Training Manual (FCTM) contained the following sentence concerning – Taxi speed and braking:

Page NO-040 P 4/12:
"For turns of 90° or more, the aircraft speed should be less than 10 kt."

Page NO-040 P 6/12:
"On long straight taxiways, and with no ATC or other ground traffic constraints, the PF should allow the aircraft to accelerate to 30 and should then use one smooth brake application to decelerate to 10 knots. The PF should not "ride" the brakes. The GS indication on the ND should be used to assess taxi speed."

The aforementioned FCTM information is given during training on the Full Flight Simulator (FFS) as shown below:



Thrust reversers

The FCOM standard operating procedures contained the following sentence concerning – Landing:

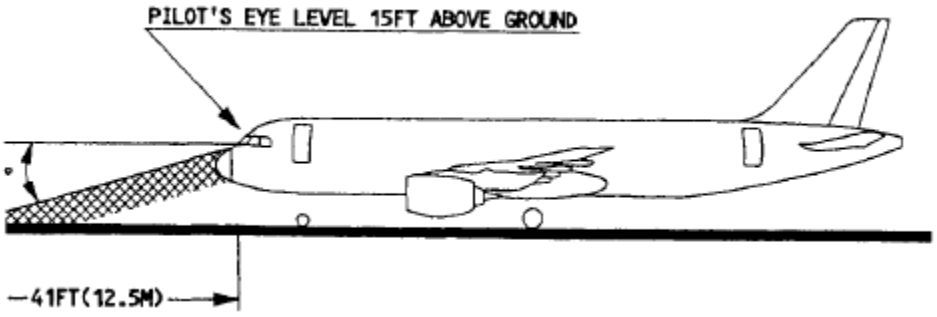
"AT 70 KT

BOTH THRUST LEVERS……..REV IDLE

AT TAXI SPEED (before leaving the runway)

BOTH THRUST LEVERS……..FWD IDLE".

Visual ground geometry
The pilot's eye level is approximately 15 feet / 4.57 meters above the ground as shown on the drawing below.



Meteorological information
The following weather reports (METAR) were available from EKCH:

210650 METAR ekch 210650z 13010kt 3000 br few002 sct004 bkn006 07/06 q1019 tempo 5000 bkn010=
210720 METAR ekch 210720z 13012kt 3000 br few003 sct006 bkn008 07/06 q1019 tempo 5000 bkn010=
210750 METAR ekch 210750z 15013kt 5000 br few003 sct006 bkn010 08/06 q1019 tempo 4000 bkn008=
210820 METAR ekch 210820z 16012kt 6000 sct006 bkn010 08/06 q1019 tempo sct010=

Aerodrome information
General
Copenhagen Airport, Kastrup (EKCH) is located 4,4 NM southeast of Copenhagen.

Runway in use for landing at the time of the serious incident was RWY 22L.

At the time of the serious incident, the Automatic Terminal Information Service (ATIS) arrival at EKCH reported among other information the following sentences:

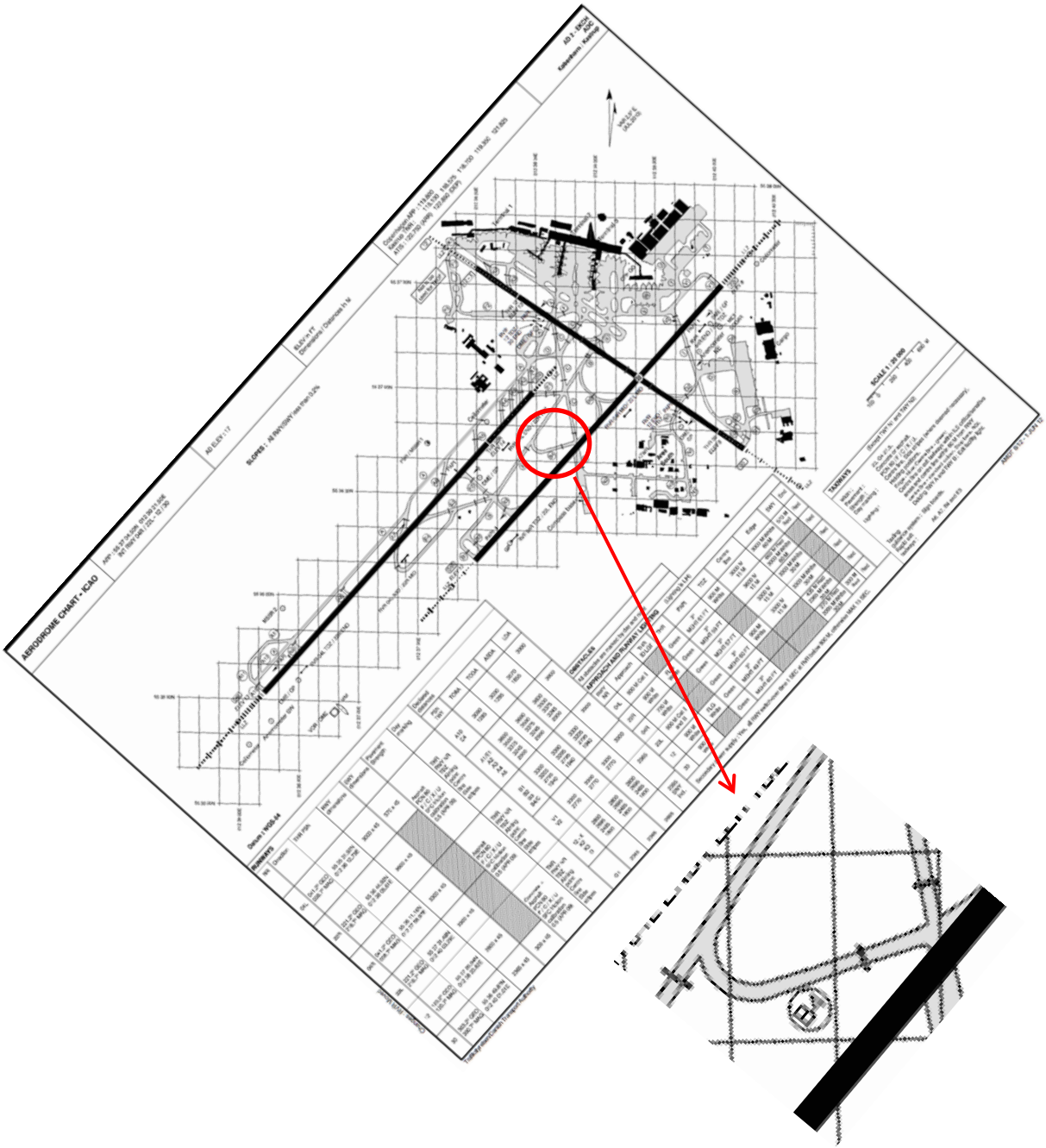
- *"RWY 22L to be "Damp".*
- "*After landing expedite vacating the runway*".

According to the Aeronautical Information Publication (AIP) Aerodrome Chart EKCH TWY B4 was defined as a "rapid exit taxiway".

The TWY B4 design was approved by the Danish Transport Authority in accordance to ICAO Annex 14 standards.

Aerodrome chart – EKCH is shown below (north up).

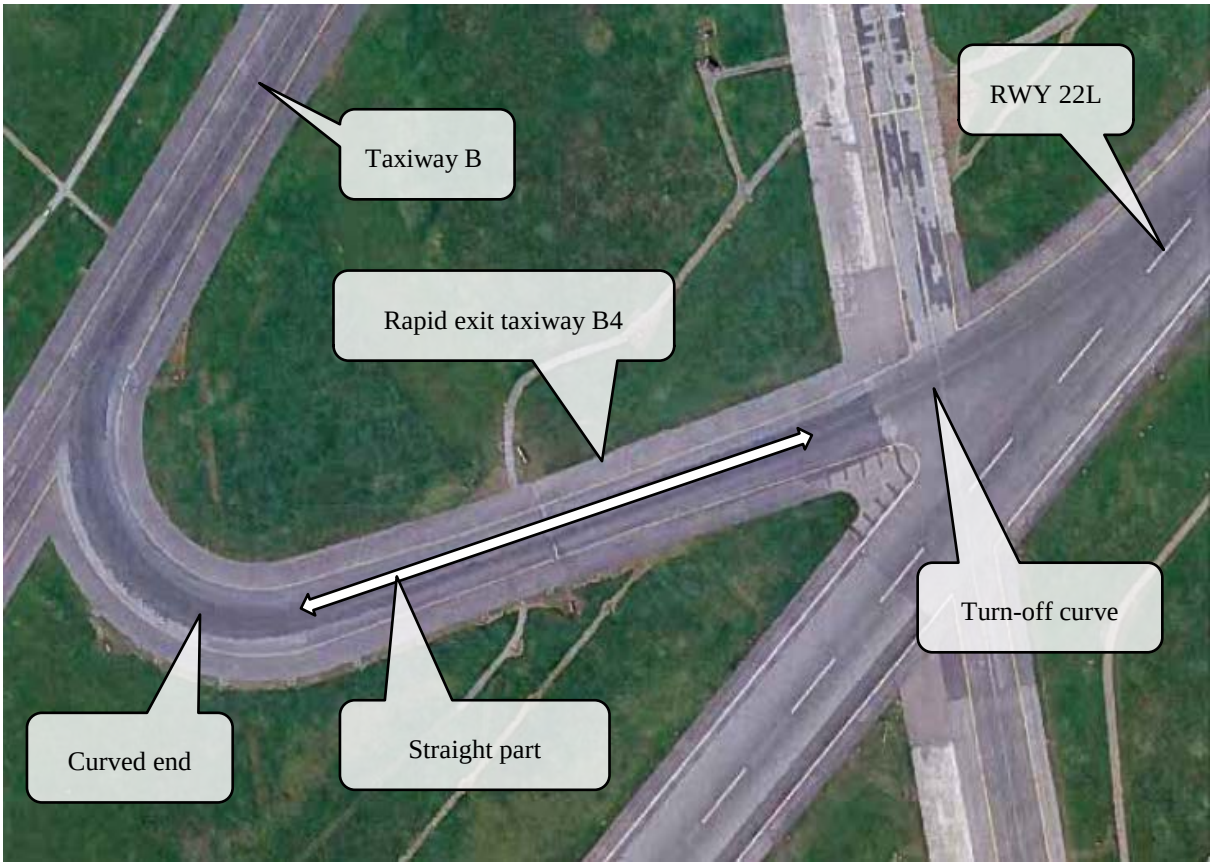
TWY B4 (shown in the red circle) is located 1940 meters from the threshold of RWY 22L.



TWY B4 geometry:

Angle of the turn-off curve:	30°
Radius of the turn-off curve (*R*):	543 meter
Straight part:	226 meter
Angle of the curved end:	142°
Radius of the curved end (*R*):	76 meters

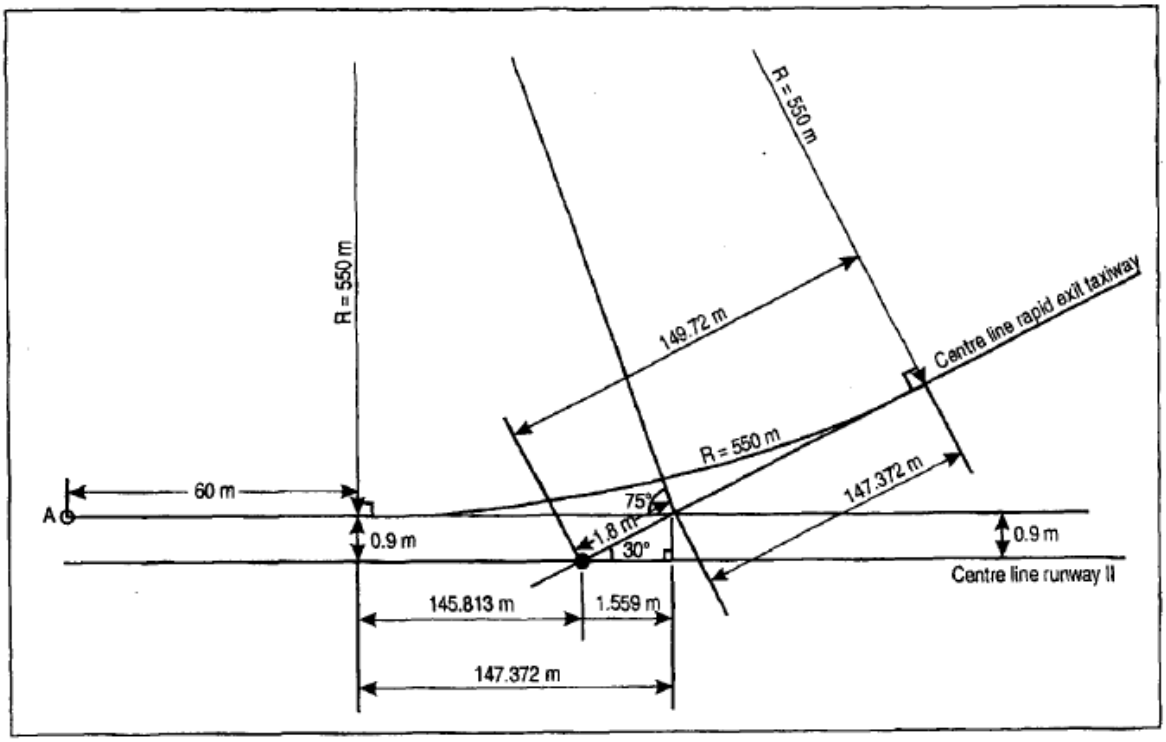
TWY B4 shown below.



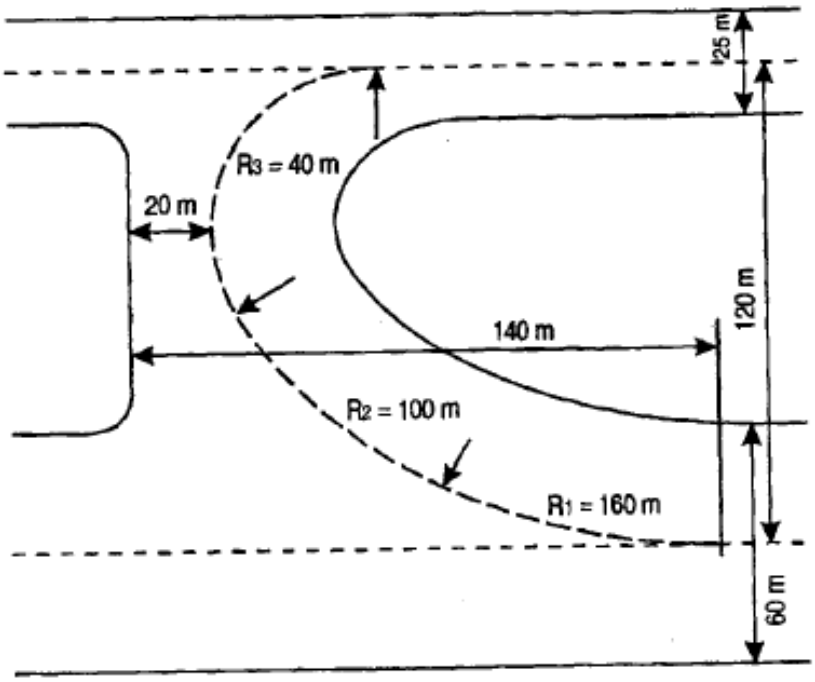
ICAO Annex 14 information about taxiways
The information given in this section was based on the available information found in the ICAO Aerodrome Design Manual Doc. 9157. Part II.

A rapid exit taxiway is a taxiway connected to a runway at an acute angle and designed to allow landing aircraft to vacate at higher speeds than are achieved on other exit taxiways thereby minimizing runway occupancy times.

Below is an example of a rapid exit TWY turn-off curve design (not EKCH).



Below is an example of a rapid exit TWY design showing *R* figures of the curve design (not EKCH).



Taxiway curves should be compatible with the maneuvering capability and normal taxi speed of the aircraft for which the taxiway is intended.

The table below shows values of allowable aircraft speeds for given radius (*R*) of curvature based on a lateral acceleration of 0.133 g (dry surface).

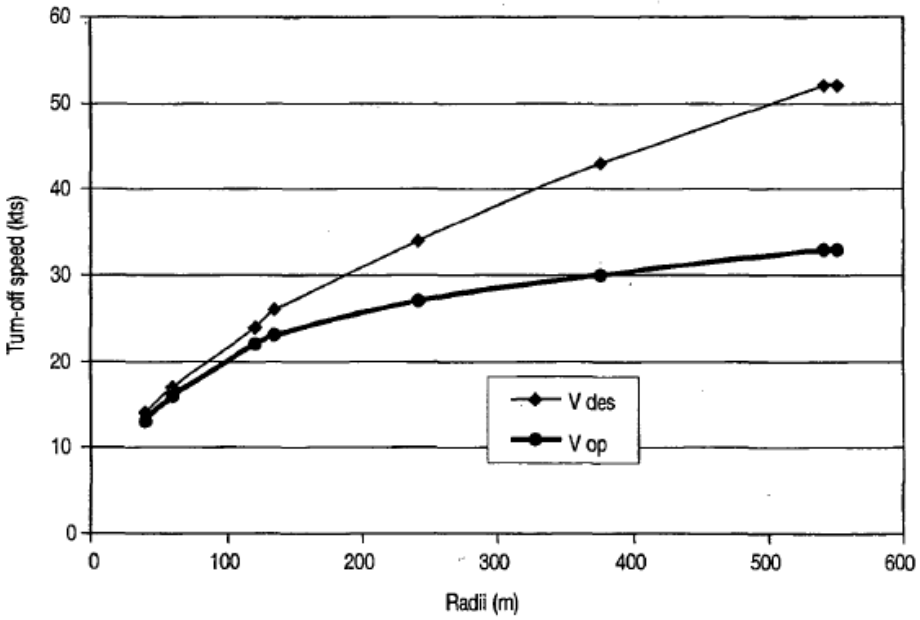
The AIB-DK has added a theoretical calculated value of allowable aircraft speed for the curved end of TWY B4 (*highlighted yellow*).

Aircraft speed (GS) (kts)	**Radius of curve (*R*) (m)**
8.6	15
17.2	60
19	*76*
25.9	135
34.5	240
43.1	375
51.8	540

The velocity in the turn is a function of the radius of the curve (*R*) - where *R* is in meters - and the lateral acceleration (*f*). Thus, if it is assumed that the lateral acceleration is limited to 0.133 g:

$$V = (127.133 \times (f) \times R)^{1/2}$$
$$= (127.133 \times 0.133\ R)^{1/2}$$
$$= 4.1120(R^{1/2})$$

The graph below shows aircraft turn-off speed versus the radius of a rapid exit taxiway turn-off curve.



The graph is based on the design exit speed V_{des} complying with a lateral acceleration of 0.133 g, the operational turn-off speed V_{op} is determined empirically to serve as the criterion for the optimal location of the exit.

A rapid exit taxiway should include a straight distance after turn-off curve sufficient for an exiting aircraft to come to a full stop clear of any intersecting taxiway.

The straight distance should not be less than 75 meters when the intersection angle is 30° (aircraft turn-off speed V_{des} 52 kts V_{op} 33 kts).

Flight recorders

Data from the Flight Data Recorder, Cockpit Voice Recorder and the Aircraft Condition Monitoring System was used in the investigation.

Impact information

The aircraft impacted the B4 location and B direction sign located in the grass area close to the taxiway (left picture below). The nose landing gear was covered with dirt but undamaged (right picture below).

Broken parts of the B4 location and B direction sign were found inside the engine behind the air inlet fan.

The left engine air intake and the lower engine cowling were damaged.

On the pictures below it can be revealed that the nose wheel was skidding on the taxiway asphalt from the point of the beginning of the curved end (at the centerline) to the grass area (marked with yellow arrows).

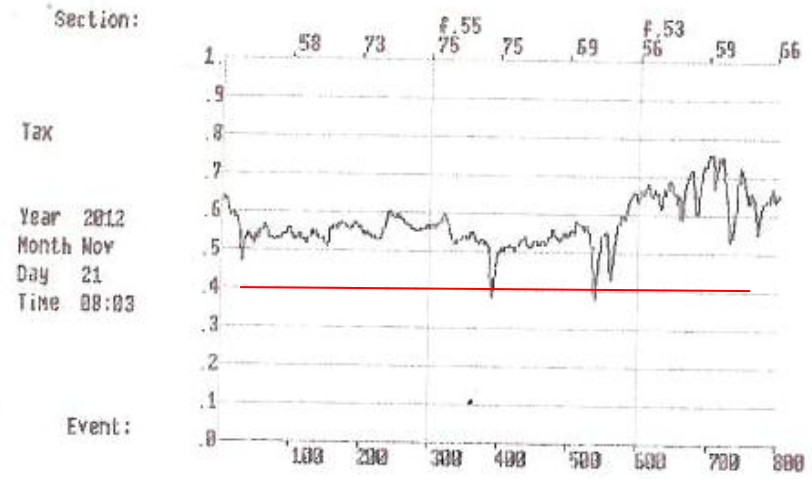
Test and examination

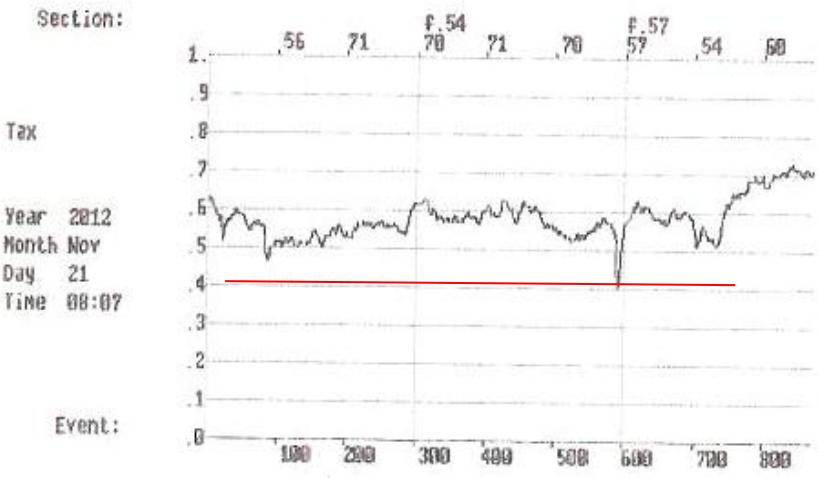
TWY B4 condition

It appears from the pictures above that the taxiway was damp and drying up.

The AIB-DK inspected the taxiway condition immediately after the serious incident had occurred and revealed that the granular asphalt was rough when touched and not slippery.

From the friction test strips shown below, it can be revealed that the friction was good (measured friction coefficient 0.40 and above) Friction coefficient 0.40 marked with red lines.

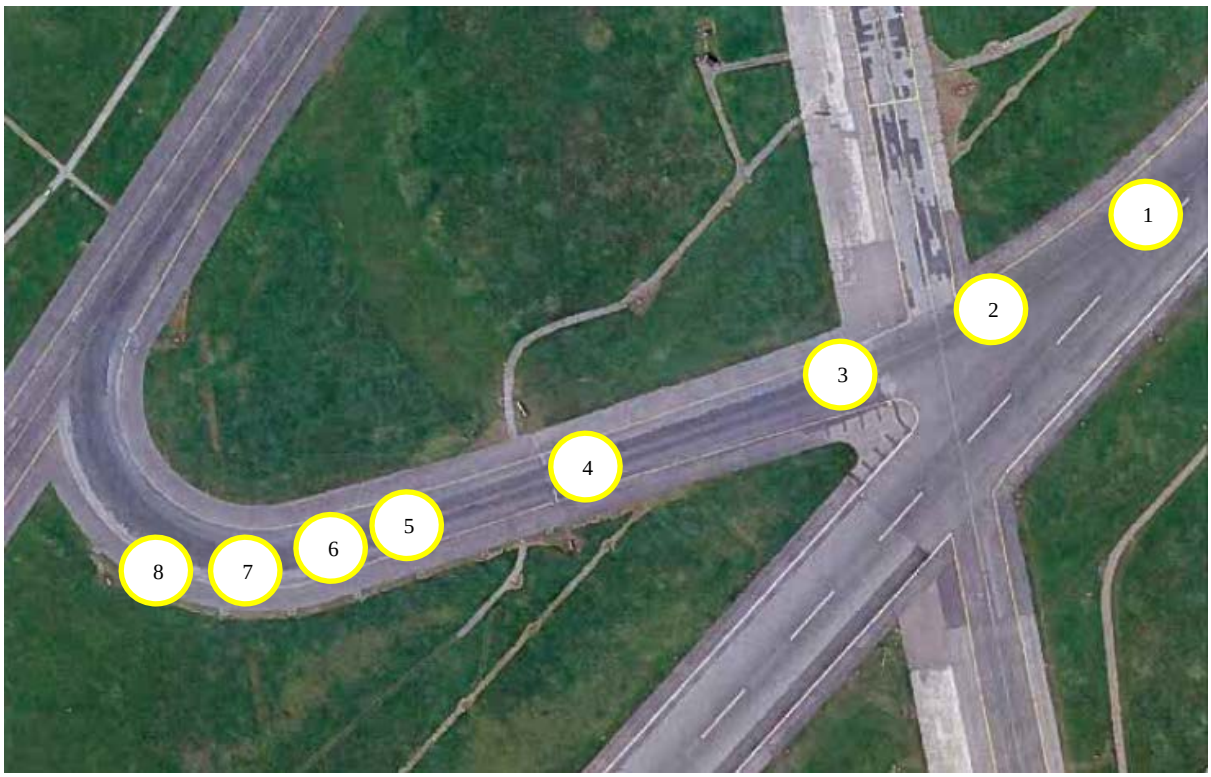




Recorded aircraft data
Aircraft Condition Monitoring System (ACMS) data in relation to aircraft position on TWY B4 shown below. The time period between pos. 1 - 8 was 26 seconds.

The brake pressures (not shown) correspond to the brake pedal positions (high units / high pressure).

Pos. at TWY B4	HDG	GS (knots)	NWS ref angle	Lateral Accel. G	Brake pedal pos. L/H (units)	Brake pedal pos. R/H (units)	Brake temp Disk 1 L/H	Brake temp Disk 2 L/H	Brake temp Disk 3 R/H	Brake temp Disk 4 R/H
1	227,4°	45	-3	0,051	14	13	71	79	64	66
2	238,7°	45	-1,25	0,129	5	0	73	84	70	69
3	244,8°	46	-3,63	0,066	12	0	75	87	76	70
4	246,9°	44	-3,75	-0,043	37	0	80	93	81	74
5	247,1°	36	-12,88	-0,043	40	12	86	102	86	77
6	247,6°	31	-47,75	-0,008	31	18	87	106	90	78
7	260,4°	27	-70,5	0,141	0	0	91	115	95	80
8	278,3°	26	-73,38	0,148	0	0	95	121	96	83



From the ACMS data it could also be revealed that the CMD deselected both thrust levers when the aircraft reached 60 knots GS. The reversers went to the FWD IDLE position before the aircraft reached the turn-off curve of TWY B4.

No technical faults or deficiencies were found on the aircraft.

Examination of the cockpit voice recording
The communication in the cockpit was calm and gave no impression of stress at approach to RWY 22L, landing at 22L or during the serious incident at TWY B4.

The FO – who was an experienced A320 pilot – did not interfere in the situation at TWY B4 before the aircraft came to a full stop in the grass area. He then suggested that they should start up the APU and shut down the engines.

Cockpit crew interviews
The visual perception of the taxi speed on TWY B4 of both pilots was; that it was normal and not too high. They felt that everything was normal until the aircraft began to skid on the curved end of TWY B4.

The CMD did not observe the taxi speed (GS) indicated on the Navigation Display (ND) top left.

Both pilots mentioned some factors that unknowingly could be contributing to the use of high taxi speeds.

- The airline was highly focused on “on-time performance”.
- The permanent ATIS information to expedite vacating the RWY.
- The airport and the ATC wished to have a smooth traffic flow on the airport.

The CMD explained that he was not yet experienced in use of the A320 aircraft series brakes and that the brake pedals design was different from the MD-80 series aircrafts. He explained that he “fiddled” with the brakes to avoid a “hot brake” problem as he would have done on the MD-80 series aircraft. It appeared in his mind that he observed a right brake hot indication light and therefore he mainly used the left brake on TWY B4.

The FO was occupied with the checklists and was unaware of the situation before the aircraft began to skid of the TWY.

Organizational and management information
From interviews and accident/incident databases, it was revealed that the airline had suffered from similar incidents at the curved end of TWY B4 in the past.

Latest incident was to a McDonnell Douglas MD-87 on 11th September, 2012. The aircraft was unable to follow the centerline of the curved end of TWY B4. The aircraft exceeded the left yellow side marking off TWY B4 as the nose wheel was skidding. The aircraft stopped on the asphalt close to the grass area (pictures below).


FDR data showed the following. When the aircraft turned-off to TWY B4, the indicated airspeed (IAS) was 58 knots and the lateral acceleration reached 0,138 G.
When the aircraft skidded of TWY B4, the IAS was 31 knots or below.

Ground speed data was not available from the FDR.

The airline's interpretation of the TWY B4 incidents was focused on the TWY itself and a company NOTAM was published to inform cockpit crews that the TWY B4 could be slippery when wet.
The cockpit crews were aware of the information that TWY B4 could be slippery when wet.
Focus among pilots was placed on the fact that the TWY B4 was defined as a "rapid exit taxiway" and not the fact that the curved end of the TWY B4 was a sharp angled curve.

According to the cockpit crew, the Air Traffic Control (ATC) expected that cockpit crews expedited vacating RWY 22L.

The cockpit crews knew that the turn-off curve of B4 was able to handle relative high aircraft taxi speeds and therefore the sharp turn at the end of B4 was not in their first thoughts.

On-time performance was essential to the airline and one of the effects was that the pilots rushed to get to the gate after landing.

Additional information
The CMD had previous many years of experience on the McDonnell Douglas MD-80 series aircraft at the same airline.

McDonnell Douglas MD-81/82 information
The main wheels have multidisc metal brakes.
Steel brake wear is directly proportional to the kinetic energy absorbed by the brakes. Maximum steel brake durability can be achieved during taxi by using a large number of small, light brake applications, allowing some time for brake cooling between applications. High airplane gross weights and high brake application speeds tend to reduce steel brake durability because they require the brakes to absorb a large amount of kinetic energy.

The brake temperature is measured from all four brakes (two for each main landing gear) and is displayed on the brake temperature gage in the cockpit. It indicates the selected or the hottest brake temperature.

An overheat light will illuminate when brake temperature exceeds 305° C.

A nose wheel steering hand wheel is located on the left side console in the cockpit.
The steering hand wheel can steer the nose wheel up to 82° in either direction.
A scale on the steering hand wheel indicates the relative position of the nose wheel.

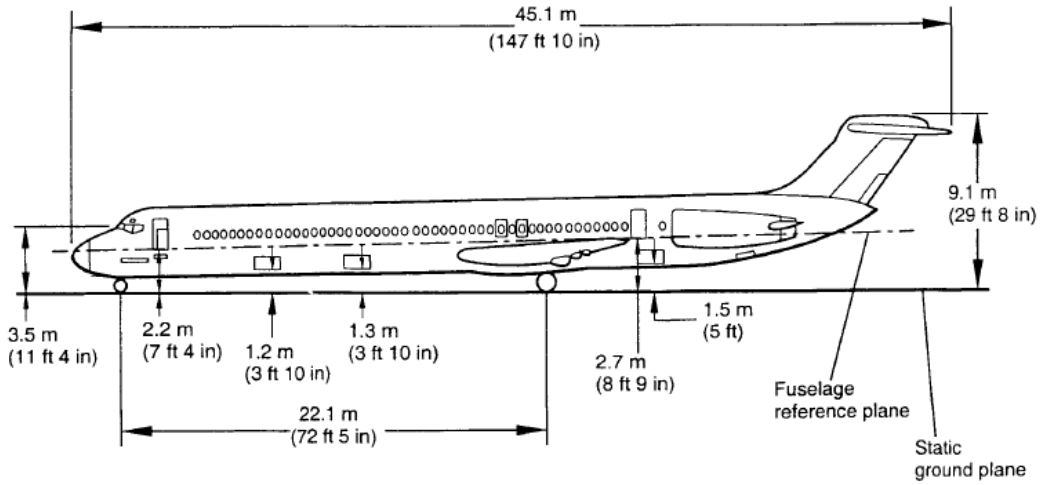
According to MD pilots interviewed by AIB-DK, vibrations from a skidding nose wheel are transferred to the cockpit as vibrations felt in the steering wheel and noise.

The Aircraft Operating Manual MD-80 procedures contained the following sentence concerning – Reverse thrust:

"To assist in reverse thrust setting PNF shall call "80 knots", "70 knots" and "60 knots", when passing those speeds".

"When "70 knots" has been called, select un-reverse so as to reach forward idle at 60 kt".

The pilot's eye level is approximately 3.5 meters above the ground as shown on the drawing below.



ANALYSIS

The aircraft

The aircraft had a valid Airworthiness Review Certificate.

The AIB-DK found the aircraft within the mass and balance limitations and there was no technical findings registered in the maintenance system of the aircraft.

Human factors

The cockpit crew was properly licensed.

The CMD was of the opinion that he had observed that the right brakes were warm and therefore used the left brake the most. But this was not a fact; there were no signs of any hot brake disks.
The AIB-DK relates this information to his relative low A320 series flying experience and human factors (read and process information in short time).

The AIB-DK finds the CMD's relative low A320 series experience (76 flight hours / few landings) and his MD-80 experience clearly in his mind – as knowing something like the back of one's hand – contributing to the serious incident.

The CMD's handling of the aircraft brakes and the thrust reversers confirms the above.

The CMD operated the aircraft systems as he would have operated the systems of a MD-80 aircraft.

A320 series carbon brakes can be used consistently.

In addition to this, it is the opinion of the AIB-DK that the 1.2 m higher eye level above the ground compared to the eye level of the MD-80 – in which the CMD was experienced – gave him the impression of a lower ground speed.

The communication in the cockpit was calm, therefore the AIB-DK does not find stress as a contributing factor to the serious incident.

However, the AIB-DK is of the opinion that the in general widespread focus on "on-time performance" and the permanent ATIS information to "expedite vacating the RWY" put pilots under pressure – unknowingly – to vacate the RWY fast and to get to the gate as fast as possible. This was a common point of view among pilots within the airline and obviously influenced their choice of taxi speed.

Another viewpoint related to human factors was the pilot's perception of TWY B4. The B4 was defined as a "rapid exit taxiway" and the design was according to ICAO Annex 14 standards and approved by the Danish Transport Authority but, the curved end of B4 was a sharp angled curve. It is the opinion of the AIB-DK that this in general mentally was overlooked by the pilots of the airline. The mental focus was on the fact that they used a rapid exit taxiway and therefore, they were surprised when they arrived at the sharp angled curve after a relative short straight distance from the turn-off curve.

TWY B4 excursion

TWY B4 was damp but the friction tests revealed that the friction at the time of the serious incident was good.

Analyzing the ACMS data, the AIB-DK found the aircraft turned of RWY 22L at a ground speed of approximately 45 knots and that braking was performed ineffectually (mostly using the left brake) while the aircraft was rolling on the straight part of B4. The AIB-DK is of the opinion that consistently braking on the straight part of B4 could have prevented the serious incident.

From the ACMS data it could also be revealed that the aircraft entered the curved end of B4 with a ground speed approximately 12 knots above the curve design speed.

The inertia (approx. 51.000 kg / 31 knots) exceeded the nose wheel tires friction ability to turn the aircraft in the direction of the curve. As the nose wheel steering was turned right the nose wheel tires ended up with an angle to the direction of the aircraft movement of 47° to 70°. Therefore, the aircraft skidded almost straight ahead and left TWY B4.

In relation to the TWY B4 design the investigation found no deviations from the requirements described in ICAO Annex 14.

CONCLUSIONS

Ineffectual braking was a contributing factor to the high ground speed at the end of the straight part of TWY B4. The ground speed was approx. 12 knots above the curve design speed and therefore leading to the serious incident.
The inertia (mass/speed) of the aircraft exceeded the friction ability of the nose wheel tires leading the aircraft to skid of the curved end of TWY B4 into the grass area.

Contributing human factors to the serious incident was:

- The CMD's relatively low A320 series flying experience versus in memory high MD-80 series experience and the A320 series 1.2 m higher eye level above the ground compared to the eye level of the MD-80.
- Mentally pressure put on the cockpit crew to be "on-time" and the permanent ATIS information to "expedite vacating the RWY".
- The cockpit crews perception of TWY B4. It was defined as a "rapid exit taxiway" but, the curved end of B4 was a sharp angled curve that mentally was overlooked.

SAFETY RECOMMENDATIONS

The AIB-DK issued no recommendations based on this investigation.

Safety initiatives taken during the investigation

- The airline of the serious incident aircraft decided to release Flight OPS information to inform their cockpit crews about TWY B4 as follows:

  The Flight OPS information on 14th December 2012 contained among other information the following sentence:
  "The ground speed limitation for this sharp turn is only 20 knots on DRY surface and favorable circumstance. Any contamination will call for an even lower speed".

  The Flight OPS information on 21st December 2012 contained among other information the following sentence:
  "The design of the high speed exit is according to ICAO standards, with a speed limitation of 15 knots on DRY surface. This calls for a significant lower speed in wet or contaminated conditions".

- Copenhagen Airport, Kastrup decided to publish a NOTAM for EKCH as follows:

  "RWY 22L leaving rapid exit TWY B4, the curved end of TWY B4 is designed for a max 15 knots in dry conditions only. Hotspot chart will be issued SAP in AIP Denmark, AD2-EKCH-ADC".