aibn Accident Investigation Board Norway

Issued March 2018

REPORT Road 2018/01

REPORT ON TRAFFIC ACCIDENT IN KRISTIANSAND 7 MARCH 2017 INVOLVING A MOBILE CRANE

Accident Investigation Board Norway • P.O. Box 213, N-2001 Lillestrøm, Norway • Phone: + 47 63 89 63 00 • Fax: + 47 63 89 63 01
www.aibn.no • post@aibn.no

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

Photos: AIBN

TABLE OF CONTENTS

REPORT ON ROAD TRAFFIC ACCIDENT

Date and time:	7 March 2017, at approximately 8:08
Scene of the accident:	Vågsbygd, Kristiansand Municipality
Road:	Pedestrian walkway running parallel to the Karussveien road
Type of accident:	Collision with pedestrians
Vehicle type and combination:	Motorised equipment, crane type Liebherr LTM1055 -3.1
Type of transport operation:	Transfer of mobile crane for an assignment

NOTIFICATION OF THE ACCIDENT

The Accident Investigation Board Norway (AIBN) was notified of the accident by Agder police district's operations centre on Tuesday 7 March at 9:55. A parked and driverless mobile crane had skidded backwards and run into a five-year old boy who lost his life. The mobile crane was parked on a walkway that was being used as an access road for a building project. The mobile crane also ran into another three people, but they survived the accident without serious injuries.

The AIBN deployed three inspectors who arrived at the scene of the accident on the same day. Contact was established with the police and the Norwegian Public Roads Administration (NPRA) to secure the scene and the mobile crane.

SUMMARY

A mobile crane from Nordic Crane Sør AS set out to perform a lifting assignment for a building project at Karuss School in Kristiansand on 7 March 2017. The mobile crane arrived at the site at approximately 8:00. The crane driver stopped and engaged the mobile crane's parking brake at the top of the pedestrian walkway that runs parallel to the Karussveien road. He left the driver's cabin to inspect the driving conditions together with a colleague (a driver's mate who was to assist him during the assignment). The walkway surface was slippery, and it had not been salted or sanded.

Shortly afterwards and without any warning, the mobile crane started to skid uncontrolledly down the walkway. The front wheels were blocked by the parking brake, while the wheels on the second and third axle turned freely. The crane driver made an unsuccessful attempt to climb into the cabin to stop the mobile crane.

There were three pedestrians in the walkway below the mobile crane: a mother and two children on sledges. The driver's mate realised that the pedestrians were in danger and ran towards them to warn them and try to bring them to safety. All four people ended up under the mobile crane, but the driver's mate was able to escape and helped to free the mother and one of the children. The five-year-old boy remained trapped until he was brought out by the rescue services. He later died from the injuries he had sustained.

During the AIBN's investigation, both the service brake and the parking brake on the mobile crane's second axle were found to be defective. The braking power on the front axle was not sufficient to prevent the heavy mobile crane from skidding, given that the tires had limited road grip.

The investigation also found the crane company's maintenance procedures to be inadequate. After the accident, the crane company has therefore implemented several measures to improve the maintenance of the technical condition of its mobile cranes. Approximately two months before the accident, a certified inspection by an enterprise of competence as required by the Working Environment Act did not find anything wrong with the brakes. The AIBN's investigation has shown that the brake system was probably also defective at that time.

Even though the mobile crane is registered and subject to the requirements of the Road Traffic Act, periodic roadworthiness tests are not required on account of its age. The AIBN has previously pointed out shortcomings relating to official inspections of mobile cranes in connection with an accident involving a mobile crane at Smestad in Oslo in 2007 (Report Road 2010/02). The accident in Kristiansand shows that the AIBN's safety recommendations have not been adequately followed up and that uniform inspection procedures to ensure road safety have yet to be introduced for mobile cranes. As a consequence of the present investigation, the AIBN submits two new safety recommendations to the Norwegian Public Roads Administration and the Labour Inspection Authority.

The investigation has also shown that no adequate risk assessment or regulation had been carried out relating to use of the pedestrian walkway in connection with the municipal building project at Karuss School, as required by inter alia the Road Sign Regulations. As a consequence of the accident, the AIBN therefore also submits a safety recommendation to Kristiansand Municipality.

1. FACTUAL INFORMATION

1.1 Sequence of events

A mobile crane from Nordic Crane Sør AS had been hired to carry out a lifting assignment at 9:00 on 7 March 2017 in connection with a building project at Karuss School in Vågsbygd in Kristiansand. That morning the mobile crane was driven from Nordic Crane Sør's facilities in Rigetjønnveien 50 to Karuss School, a drive of about 4 km.

Figure 1: The black circle shows where the mobile crane started out from. The red star shows the site of the accident. Map: © Norwegian Mapping Authority

The crane driver had carried out lifting assignments on the site on two previous occasions. One of his colleagues arrived in a separate car to take on the role of driver's mate during the assignment. As on previous assignments, the mobile crane used the walkway[1] that runs parallel to the Karussveien road for access to the building site, between Karuss Kindergarten and Karuss School.

The mobile crane arrived at Karussveien at approx. 8:00 and, assisted by the driver's mate, the crane driver backed onto the walkway from the access road to Karuss Kindergarten. The intention was to drive the mobile crane in reverse down the walkway and then up to Karuss School. The crane driver stopped the mobile crane temporarily in the upper part of the walkway, which was relatively flat. He intended to assess the local driving conditions and whether it was necessary to use the tyre chains. The crane driver put the mobile crane in neutral and engaged the parking brake before he left the vehicle.

Both the crane driver and the mate observed that the walkway surface was slippery from snow and snow-clearing, and that it had not been salted or sanded. While they were assessing the driving conditions together, the mobile crane started to skid down the

[1] The walkway was defined as a walkway under the regulations, but was not signposted. See section 1.11.

walkway; the front wheels were blocked while the wheels on the second and third axles were turning. At the same time, three pedestrians – a mother and two children on sledges, came walking up the walkway in the direction of Karuss Kindergarten. The area had not been cordoned off, and there was no warning to indicate that the walkway would be used by the mobile crane. The driver's mate realised that the pedestrians were in danger and ran towards them to warn them and try to bring them to safety.

The mobile crane continued to roll downhill, partly skidding across the verge on either side of the walkway until it hit a steep rockface. Both the driver's mate and the three pedestrians ended up underneath the mobile crane, but the driver's mate quickly managed to get out without assistance. He immediately tried to free the other pedestrians who were trapped. He retrieved a support leg from behind an exterior panel on the left side of the crane to raise the rear part of the mobile crane. The woman and one of the children were able to get out from the area under the rear part of the crane and the steep rock.

At 8:23, the second child – a five-year-old boy, was brought out by the rescue services who had arrived on the scene. The boy was critically injured and transferred by ambulance to Sørlandet Hospital. He later died from the injuries he had sustained in the accident.

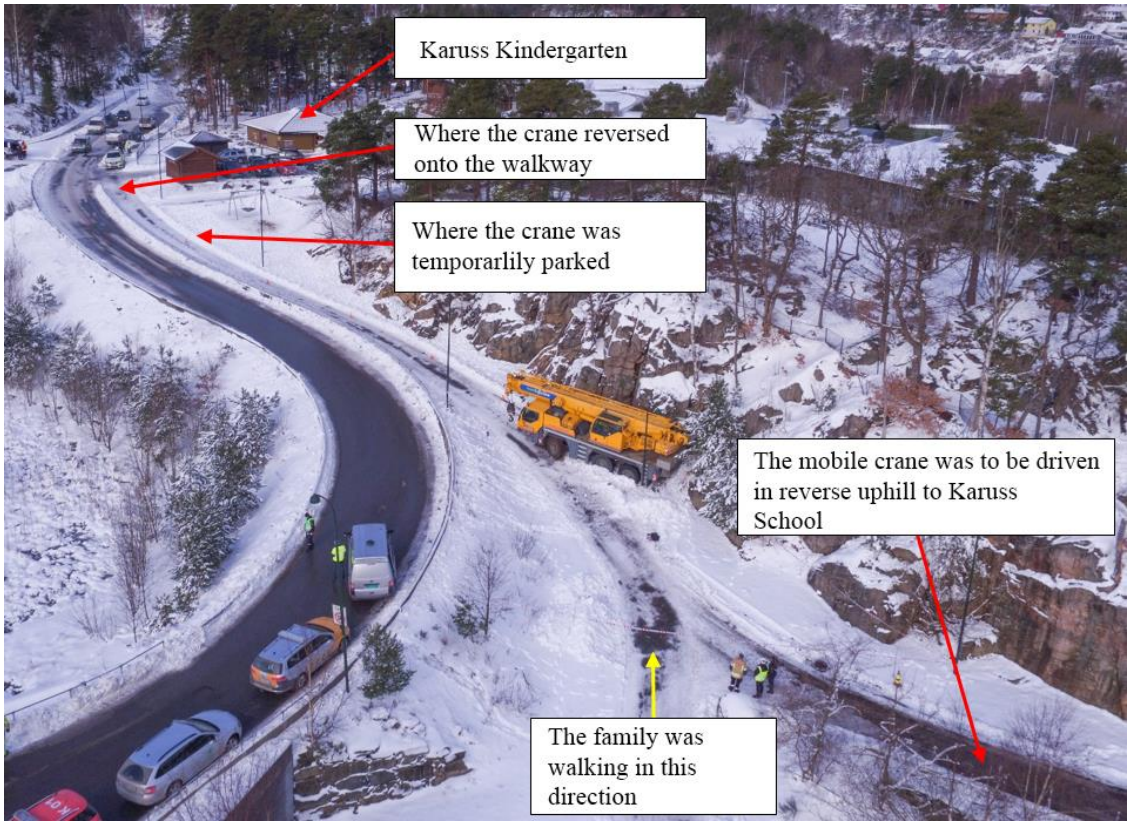


Figure 2: Drone photo showing Karussveien, parts of the walkway network and the site of the accident. Photo: The police. Illustration: AIBN

1.2 Personal injuries

One five-year-old child died as a consequence of being hit by the mobile crane. A three-year old child and the mother were lightly injured. A fourth person – the crane driver's mate, was lightly injured.

1.3 Survival aspects

A witness called for an ambulance at 8:08 and notified the fire service of the accident at 8:11. The police were notified of the accident at 8:09, and immediately sent officers to Vågsbygd together with extensive resources from the fire and health services. The rescue services arrived at the scene of the accident at approximately 8:20. At that time, the five-year-old boy was still trapped underneath the mobile crane. The mobile crane was moved forward to free the child, and the tyres were fitted with chains. Support legs belonging to the mobile crane were also used to raise the rear part of the vehicle. The child was freed at 8:23 and the critically injured boy was immediately transferred to Sørlandet hospital by ambulance.

1.4 Damage to the vehicle

The mobile crane sustained some minor damage on the right side of the vehicle when it collided with the rockface.

1.5 Other damage

One light pole on the side of the walkway was damaged in the accident. There was no other damage to the infrastructure.

1.6 The scene of the accident

The walkway had been cleared of snow along a belt of approximately the same width as the roadway. The cleared lane measured 3.05 metres and the gradient at the top of the slope, where the mobile crane was temporarily parked, was approximately 3°. From the place where the mobile crane was parked to the accident scene, the slope was almost 11%.

The structure of the front wheels' tyre tracks changed approximately 25 meter from the start of the walkway (see figure 3 first cone). The following is reproduced from the police documents:

> *Approximately 25 metres from the start of the walkway, the tyre tracks from the right front wheel changed character. A clear imprint of the tyre tread pattern changed to a more glossy tread pattern. The skid mark measured approximately 46 metres. The same type of change, although less pronounced, could be observed in the tracks left by the left front tyre. The glossy tracks from the left front tyre became clearer further down the slope. The wheels on the two rearmost axles had left imprints of the tyre treads in the tracks, indicating that they rotated without skidding.*

Figure 3: Tyre tracks and final position of the mobile crane. The first cone marks where the tyre track from the right front tyre changed character. Photo: The police

Approximately 17 metres down from where the crane had been parked, the AIBN observed scratch marks on the railing and debris from the mobile crane; see figure 3. Figure 4 shows the measured tyre tracks left by the mobile crane's front wheels on the walkway until it reached its final position.

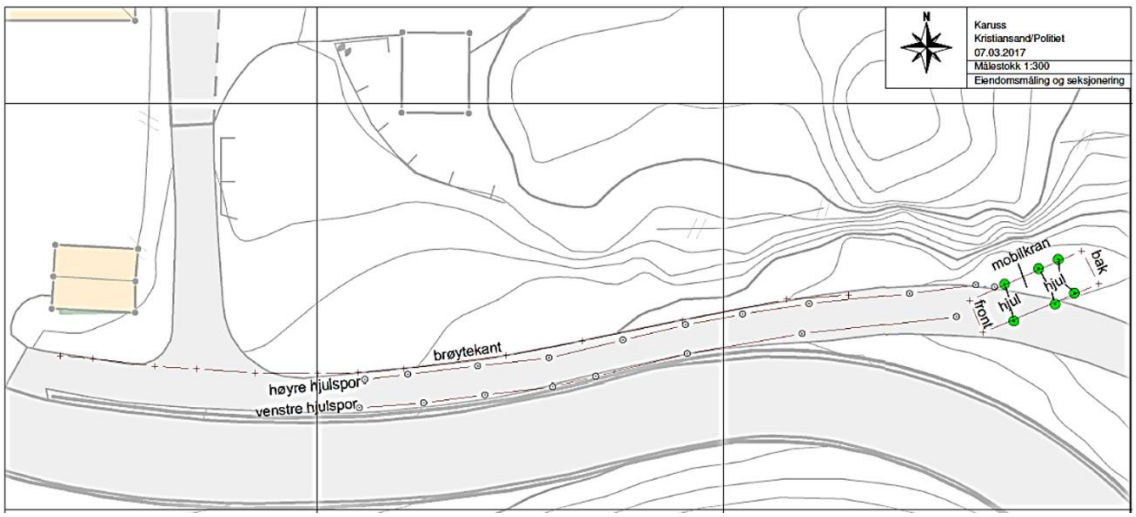


Figure 4: Sketch showing the tyre tracks left by the mobile crane's front wheels along the walkway until the vehicle reached its final position. Illustration: The police

1.7 Road users

1.7.1 The crane driver

The mobile crane's driver was 51 years old and a Norwegian national. At the time of the accident the crane driver had been working for Nordic Crane Sør AS as a crane driver for

ten years. He held proficiency certificates for several types of construction plant, including mobile cranes (G1), and a driver's licence that included lorries (CE). The crane driver had often driven/operated the mobile crane in question. He had driven the crane for 7-8 years.

The AIBN has been informed that the crane driver performed simple maintenance only and reported any defects by filling in machinery inspection reports, which were handed in to the employer. He had not found anything wrong with the mobile crane in the morning before setting out for the assignment. Nor did he notice that the surface was particularly slippery when he braked to stop on the pedestrian walkway, and he parked on a relatively flat section.

1.7.2 The driver's mate

The mate who assisted when the mobile crane was accessing the building site was a 54 year old Norwegian national. He had worked for Nordic Crane AS since 1984 and taken up the position of crane driver in 1986.

1.7.3 The pedestrians

The three pedestrians who were hit by the mobile crane were a woman aged 39 years, her three-year-old daughter and five-year-old son. All three were Russian nationals. The woman was walking uphill with her children when she noticed the mobile crane coming down the walkway. No physical barrier had been erected on the walkway and nobody warned them not to enter the area.

1.8 Vehicle and load

1.8.1 General description of the mobile crane

The mobile crane was registered to Nordic Crane Sør AS. It was acquired in connection with the takeover of another company. The mobile crane was a Liebherr UTM 735, model LTM 1055-3.1. When it was first approved by the NPRA on 18 December 2006, it was classified as motorised equipment covered by the Regulations of 4 October 1994 No 918 on Technical Requirements for and Approval of Motor vehicles, Parts and Equipment (the Motor Vehicle Regulations). The crane was built in accordance with Directive 98/37/EC (the Machinery Directive). According to the vehicle registration certificate it had an unladen weight of 35.7 tonnes, permitted axle loads of 12 tonnes and a maximum authorised weight of 36 tonnes. It was 2.54 metres wide and 11.87 metres long.

The NPRA had issued a general exemption for using a mobile crane with a maximum authorised weight of 36 tonnes and permitted axle loads of 12 tonnes on the road, provided that the axle loads did not exceed 10 tonnes while it was being driven on the road (Use class 'BK10').

According to the odometer, the mobile crane had travelled 80,772 km. The actual loads were 13,560 kg on the first axle, 14,700 kg on the second axle and 15,340 kg on the third axle. This means that the crane had an overload of 7.6 tonnes compared with the authorised total weight as stated in the vehicle registration licence and in the exemption. This was because the mobile crane was carrying the counterweights that were to be used for the lifting assignment.

1.8.2 The structure of the brake system

The mobile crane had a compressed air braking system, with wheel brakes of the Simplex expanding wedge type. According to BPW Hofstad AS[2], agent for Wabco's brake systems in Norway, this type of wedge brake is still being used on mobile cranes.

The service brakes are operated from the driver's seat using the brake pedal. There is a separate control system for the parking brake, which is constructed to engage the wheel brakes on the first and second axle only, so as to meet the requirements of the Motor Vehicle Regulations.

The parking brake was of the spring brake type, activated by a spring when bleeding the pressure from the brake cylinders. The wheel brake system is a 'closed' system, so that inspection of the condition of the brakes (brake band, clearance and brake shoes) must be carried out through the inspection hatches in the brake shields.

1.8.3 In-situ technical examination of the brakes

The mobile crane was transported to Kristiansand Driver and Vehicle Licensing Office on 7 March 2017 for technical examination. The NPRA carried out physical brake tests and technical examinations at the driver and vehicle licensing office. The mobile crane dealer assisted during the dismounting of the wheel brakes on the second axle. The AIBN participated during parts of the examination.

1.8.3.1 *Retardation measurements using the mobile crane*

The AIBN, the Police and the NPRA carried out retardation measurements[3] with the relevant actual weights under dry driving conditions. Retardation measurements with engaged service brakes showed a mean retardation of 3.27 m/s^2.

According to the Motor Vehicle Regulations, the service brakes are required to have a minimum braking power of 4.4 m/s^2 at the time of registration. The parking brake system is required to keep the vehicle stationary on a slope with a gradient of 16% or more, when fully loaded.

1.8.3.2 *Technical inspection of the mobile crane's brakes by the NPRA*

The mobile crane's brakes were also examined by running brake tests at Kristiansand Driver and Vehicle Licensing Office, from which we quote the following:

> *'The results of this test showed that the braking action on the first axle was approved, the braking action of both the service brake and the parking brake was defective on the second axle and the braking action on the third axle was approved. The parking brake shall normally act on both the first and second axles on this mobile crane, but it only acted on the first axle.'*

In examinations of the technical condition of the vehicle part of the mobile crane carried out by the NPRA it was concluded that the brakes' self-adjusting mechanism had not been effective on the second axle, so that the clearance between the brake band and drum

[2] http://www.bpw.no
[3] Test of the mobile crane's braking capacity during driving, with the aid of a separate instrument for retardation readings.

became too wide. This resulted in no braking action on the second axle. The clearance between the brake band and drum shall normally be approximately one millimetre. The NPRA measured the thickness of the brake band on the second axle to be approximately 16 millimetres. New brake bands have a thickness of 18 millimetres and can be worn down to 5 millimetres before they have to be replaced.

1.8.4 Technical examination of wheel brake components by the AIBN

The wheel cylinders were marked with identification no 160113 on the left side and 130706 on the right side. According to BPW Hofstad AS, this indicated the production date, i.e. that the wheel cylinder on the left side had been produced on 16 January 2013, and the one on the right side on 13 July 2006. The ID plate on the brake cylinder on the left side was marked with 13032, and, according to BPW Hofstad AS, this was also an indication of the production date, namely day 2 in week 3 in 2013. There was no mark on the right side. This shows that both the wheel cylinder and brake cylinder had been replaced after 2013. The wheel cylinder on the left side was mounted with the arrow pointing the opposite way from the direction of rotation, but this is of no consequence for the self-adjusting function, according to the brake manufacturer Wabco.

1.8.4.1 *Description of components and functions*

The AIBN wanted to find out why the compressed air being supplied to the brake cylinders on the second axle was not converted to braking power when the parking and service brakes were activated. The brake cylinders and wheel cylinders were dismounted, and it was observed that the expander wedge on the left side was stuck further inside the wheel cylinder housing than normal, see figure 5 and figure 6.

The brake components, including the second axle's wedge brake system, were examined in the AIBN's premises with the assistance of BPW Hofstad AS. The components were examined with a view to describing the factors that contributed to the absence of braking power when the brakes were engaged on the mobile crane in question.

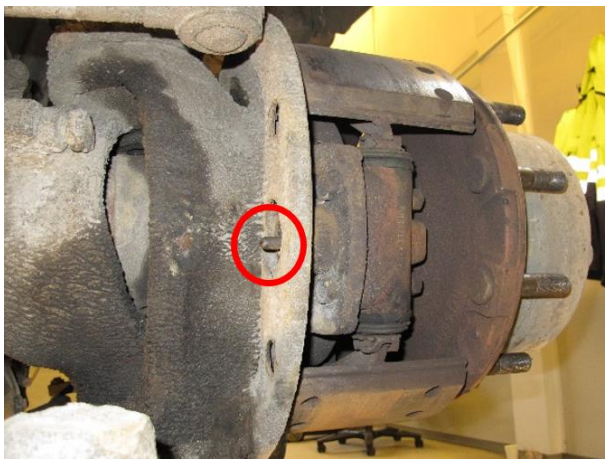


Figure 5: Push rod stuck inside the wheel cylinder on the left side. Wheel cylinder and brake shoe on the left side. Photo: AIBN

Figure 6: Push rod in expander assembly, wheel brake, left side. Photo: AIBN

1.8.4.2 *Examinations of the brake components*

The wheel brake components were assembled and function-tested. The function tests that were carried out were unable to reproduce the position in the expander assembly shown in figure 5 and figure 6.

The examination showed that the manual adjustment screws were stuck as a result of rust. The automatic self-adjusting mechanism worked provided that the correct setpoint values were used for the components; see Annex B.

Contact marks in the wheel cylinder showed that all four self-adjusting screws had been in the inner position. Figure 7 shows marks left by the self-adjusting screws. In this position, the self-adjusting screws are outside their working range.

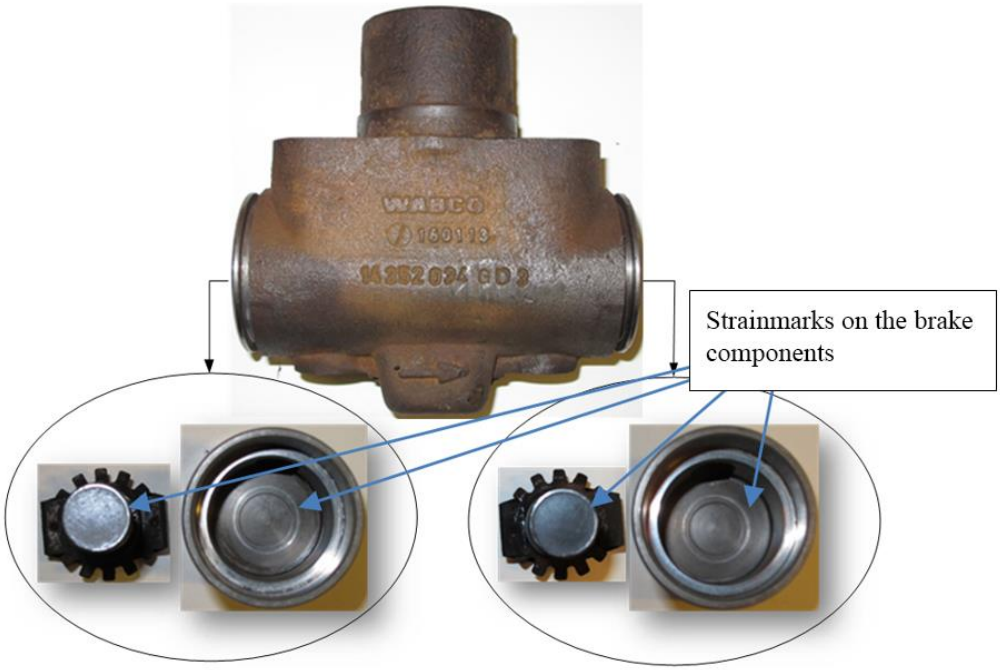


Figure 7: Physical traces of contact between the self-adjusting screw and the bottom of the wheel cylinder pistons on the left side, indicated by the blue arrows. Photo: AIBN

Marks were also found that showed how the rollers in the expander assembly had rolled over the 'top' of the wedge; see figure 8.

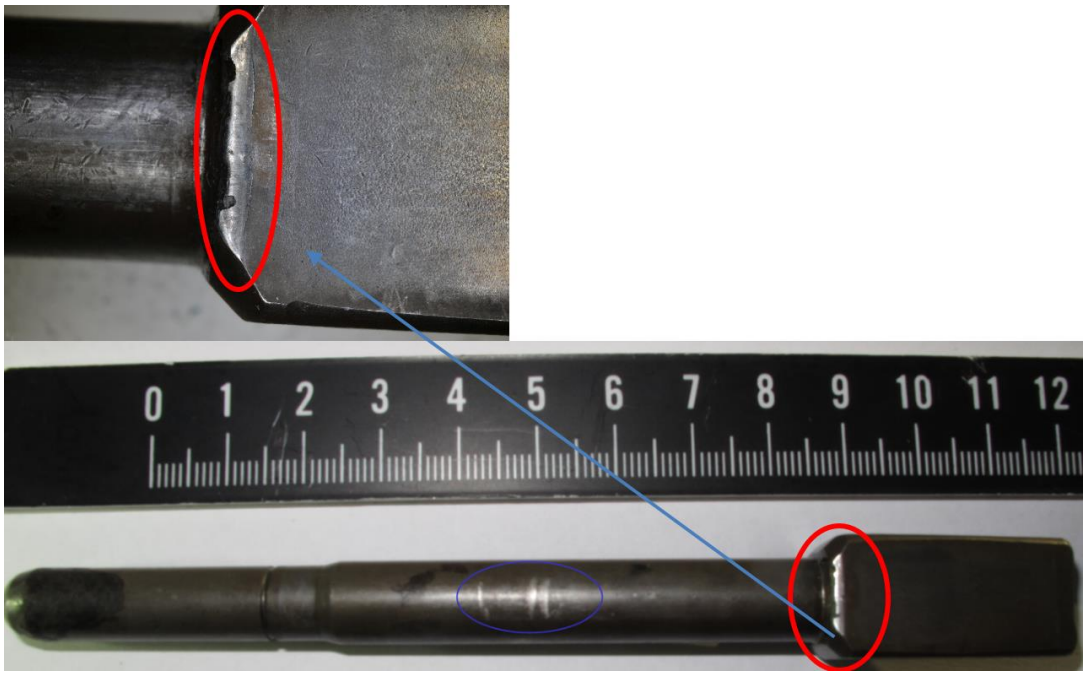


Figure 8: Traces of wear from the roller system on the cylindrical area and at the top of the wedge. Photo: AIBN

In order to find possible explanations of why the expander assembly's push rod on the left side proved to be stuck too far inside the wheel cylinder when the system was dismounted, we have compared the old components to new ones as shown in figure 9. The component on the left is shown with the push rod positioned approximately as it was when the system was dismounted from the mobile crane, while the component on the right shows the normal position of the push rod when installed.

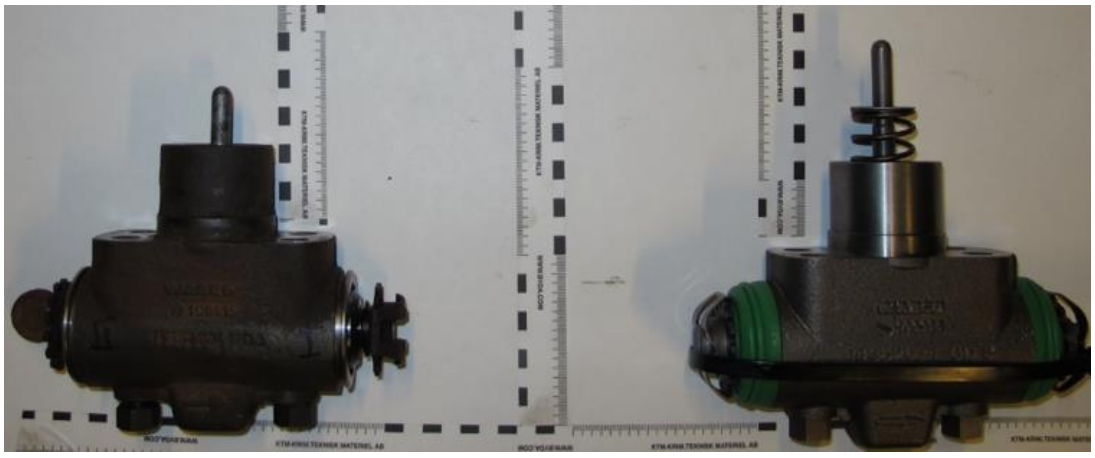


Figure 9: In the photo on the left, the expander assembly is mounted approximately as it was when it was dismounted, see figure 5 and figure 6. The photo on the right shows how the push rod should normally be positioned in the expander assembly. Photo: AIBN

1.8.4.3 *Service notices from the brake and crane manufacturers*

In service notices issued in 2004/2005, the brake manufacturer Wabco and the crane manufacturer have explained that these marks (see figure 8) can arise if the brake system has been engaged with the brake drum dismounted (see annex B and E).

The AIBN has assembled the push rod, roller cage and wheel cylinder as shown in figure 10. Here the wedge is pushed to the bottom of the housing and the rollers, including the roller cage, are positioned as indicated by the traces of load exposure in figure 8. In this case the roller position makes it physically impossible for the rollers to hook onto the bottom side of the piston as described by the manufacturers in annexes C and F.

Before it was dismounted, the push rod for the expander assembly was positioned approximately as shown in figure 11.

Figure 10: Roller cage 'slipped across'. Push rod with the wedge at the bottom of the housing and the roller cage at the transition between the wedge and push rod. Photo: AIBN

Figure 11: Assumed position of push rod and roller cage as shown in figure 5 and figure 6. Photo: AIBN

These technical findings have been sent, via the Norwegian importer, to the Nordic representative for the brake system, Wabco AB in Sweden. Wabco AB has sent them on to the brake manufacturer, Wabco GmbH in Germany.

1.8.5 Tyres

The Regulations of 25 January 1990 No 92 on use of vehicles (the Vehicle Use Regulations) require all vehicles with an authorised total weight of more than 3,500 kg being used in Southern Norway from 1 November up to and including the first Monday after the second day of Easter to have a tyre tread depth of 5 mm. However, the Directorate of Public Roads has issued a general exemption from the requirement for winter tyres during the period from 15 November up to and including 31 March for mobile cranes.

Table 1. Characteristics of and information about the mobile crane's tyres.

Axle	Manufacturer	Dimensions	Tread depth left side	Tread depth right side	Meets the requirement for tread depth
1st	Techking	385/95R25	19 mm	20 mm	Yes
2nd	Yokohama	385/95R25	8 mm	12 mm	Yes
3rd	Michelin	385/95R25	7 mm	3 mm	No, not on the right

1.9 Maintenance and inspection of the mobile crane

1.9.1 Maintenance and inspection history

1.9.1.1 *The company's maintenance and self-inspection*

Nordic Crane Sør AS's internal control manual includes inspection forms for technical equipment to be completed on a daily/weekly basis in connection with maintenance, service and repairs. Daily checks shall be carried out of oil level, cooling fluid, safety equipment, leakages and checkpoints in accordance with the instruction manual. For the most part, these checks relate to the operation of the mobile crane's lifting equipment. The brakes were not included in the daily checks.

According to the machinery inspection reporting form, Nordic Crane Sør AS carried out maintenance and control of its mobile cranes four times between 10 January and 7 February in 2017. However, it is not clear from the reports which mobile cranes (company-internal numbers) were inspected, or what type of service or checks were carried out.

According to the information received from Nordic Crane Sør AS, garage services for maintenance and repair of the mobile cranes were bought as the need arose.

The company has no procedures for function-testing brakes as described in the crane manufacturer's maintenance instructions. The AIBN has not received any documentation showing the most recent brake repairs or identifying the company that carried them out.

1.9.1.2 *Inspections by enterprises of competence*

The crane company has informed the AIBN that the mobile crane's brakes were inspected as part of the annual inspection by an enterprise of competence. The AIBN has been

granted access to the inspection reports from the annual inspections of the mobile crane that took place between 2008 and 2017. None of the brakes were marked as being defective during that period. The two most recent annual inspections were carried out by Kran og løfteteknikk AS in January 2016 and by Kolos Inspection AS on 5 January 2017, approximately two months before the accident occurred.

1.9.1.3 *Annual inspection of 5 January 2017*

It is clear from the checklist used by Kolos Inspection AS during the inspection on 5 January 2017 that the mobile crane's brake system and brake transmission lines were checked as well as the weight of the mobile crane and its counterweights. Only defects in the lubrication of the lifting appliance part of the crane were identified during the inspection, while there was no mention of defects in the vehicle part. No faults or defects in the mobile crane's brake system were mentioned in the inspection report and pertaining remarks. The mobile crane's certificate of use was renewed with validity until January 2018.

1.9.2 Inspection and maintenance procedures

1.9.2.1 *The mobile crane manufacturer's maintenance instructions*

Liebherr has drawn up instructions for regular maintenance of the mobile crane according to the number of kilometres driven. Daily, weekly and annual checkpoints are also prescribed. The requirements for visual inspection, function testing, control of braking power and interior control of the wheel brakes are described in Annex A. The following is reproduced from section 8.07, Control of the compressed air brakes:

> *2.2 Brake action test*
>
> *The brake function can be checked through the ports in the cover plates[4]. If the brake pedal is pressed down, both brake pads must touch the drum, when the brake pedal is released, the brake pads must immediately return to starting position.*
>
> *The brake action can be checked by measuring delay, brake path or by determining the braking action on a brake test station.*

According to the manufacturer's maintenance intervals for the mobile crane's brake system, daily function tests shall be carried out of the parking and service brakes.

Inspection of the brake lining, adjustment of the brakes (if necessary), replacement of the lining (if applicable) and inspection of the brake drum shall be carried out every 5,000 km. The brake drum shall be dismounted annually for inspection of the internal brake-system components. The compressed air storage tank shall be aired, the air dryer cartridges replaced and the air intake filter for the air dryer in the compressed air system shall also be cleaned annually.

[4] In the Norwegian translation of the instructions, this phrase is translated to: "*The braking function can be checked through the observation holes in the wheel caps.*"

1.9.2.2 *Kolos Inspection AS's procedure for annual inspection*

Kolos Inspection AS's procedure for annual inspection of mobile cranes states that, before commencing the inspection, the crane's documentation, user instructions, inspection log and service history shall be reviewed. A review shall also be carried out of the manufacturer's maintenance instructions (see section 1.9.2.1).

The procedure that applied to the inspection in January 2017 stressed, among other things, the importance of talking with the crane driver and/or maintenance personnel/foreman to find out whether they had registered any faults or defects in the crane, and if there were any recurring faults, or faults that arose in particular situations.

The procedure went on to prescribe inspection of the brake system for function, lubrication and damage, and that the automatic load moment indicator should be inspected visually and function tested. Verification should be carried out annually at the same time as the inspection of the lifting equipment.

The procedure prescribed use of a checklist with appendices during the inspection. Part 1 of the inspection report should include hour counter readings, while part 2 should list any faults, defects and comments relating to the work equipment. Part 3 of the inspection report listed individual checkpoints, including inspection of brakes and any brake transmission lines, as well as function tests.

1.10 Weather and driving conditions

1.10.1 Weather and driving conditions at the time of the accident

There was daylight, good visibility and no precipitation when the accident occurred. The walkway that the mobile crane drove onto had been cleared of snow after a heavy snowfall during the night leading up to 7 March.

The surface was covered in compact snow/ice where the accident occurred. The steep hill that branches off from the walkway network and leads up to the school had been salted, however, and was partly free for snow. It had been salted by the company HSH Entreprenør AS. Figure 3 shows the driving conditions.

Response and rescue personnel who first arrived on the scene remarked that the scene of the accident was very slippery. The temperature was around -3 °C when the accident occurred, but the temperature rose and much of the snow and ice had melted when the on-scene examination had been completed. Friction tests performed by the NPRA some time after the accident showed a mean friction coefficient of 0.29.

1.10.2 Winter maintenance

The relevant section of walkway is maintained during winter by a contracted municipal supplier who clears it of snow and applies sand/salt etc. to improve friction when needed According to Kristiansand's municipal authority, priority is given to areas near schools. No additional winter maintenance had been ordered in connection with the building project at Karuss School.

1.11 Road conditions

The accident occurred on a pedestrian walkway[5] that formed part of a more extensive walkway/cycleway network owned by Kristiansand Municipality; see figure 12. The mobile crane reversed onto the walkway with Karuss Kindergarten one side of the walkway and railings forming a barrier against Karussveien road on the other.

The walkway functioned as a temporary access route to the building site at Karuss School and was used for some parts of the development project. The walkway was not regulated by any signs, such as for example sign no 518 'Walkway' or sign no 521 'Walkway and cycleway'. Nor had any work notification signs been posted or barrier put in place to prevent pedestrians/cyclists from using the walkway while the mobile crane was being driven onto the building site. The walkway is not used as an access road to properties in the area.

Kristiansand Municipality has informed the AIBN that it has no fixed practice of signposting all municipal walkways and cycleways. No information has emerged to indicate that there was any doubt as to the function of the walkway, even though there were no signs along the section in question.

Figure 12: The accident site and surrounding walkway network. The arrows indicate the driving/reversing direction. Illustration: AIBN. Map: © Norwegian Mapping Authority

[5] In Kristiansand's municipal zoning plan for the area, the traffic area where the accident occurred is designated as a walkway.

1.12 Technical registration systems

The mobile crane was equipped with a tachograph as the only technical registration system.

1.13 Medical considerations

The crane driver tested negative in an expanded blood test taken after the accident. The AIBN has found no indication of use of intoxicants or other drugs and has received no other information about the mobile crane driver's medical condition.

1.14 The Karrus School project

1.14.1 Project description and planning

The project consisted of installing a ventilation system in the school buildings and was organised as a design and build project, with HSH Entreprenør AS as the design and build contractor. The building site is a built-up school plot, and the school was kept open during the building period. Karuss School is attended by 430 first to tenth year students.

1.14.2 Health, safety and working environment (HSE) plan

Kristiansand Municipality had prepared an HSE plan for the project in accordance with the Regulations No 1028 of 3 August 2009 relating to safety, health and working environment at building and construction sites (the Construction Client Regulations). The HSE plan for Karuss School did not mention access to the building site as a type of activity that could put human life or health at risk.

A document from Kristiansand Eiendom shows that Karuss School had expressed concern about conflicts between vehicles and pedestrians/cyclists during the project period. The document describes this as a focus area that will be subject to clear guidelines regarding times of delivery and use of driver's mates when making deliveries by lorry. It is also stated that the risks are identified in a risk analysis and that a separate safe job analysis (SJA) will be prepared for the activity.

1.14.3 HSE plans and procedures

Based on the contracting client's HSE plan and supporting documentation, HSH Entreprenør AS prepared an HSE plan for the project dated 9 November 2016. The HSE plan refers to tasks that must be completed, including risk analyses for the project execution phase and SJAs for critical work operations in accordance with the risk analysis.

According to the HSE plan, a rigging plan must be established, with specification of access routes to the building site and crane positions, among other things. The HSE plan also addresses risks associated with the work, identifying four situations of risk: 'collisions with pedestrians/cyclists', 'work at height', 'mobile crane operations' and 'hot work'.

Minutes of meetings kept by HSH Entreprenør AS indicate that HSA Entreprenør AS shall be notified of major deliveries and that such deliveries shall always take place before 7:30 in the morning. A driver's mate shall always accompany the driver on

delivery of large items. Barriers were to be erected when the mobile crane was rigged and carrying out lifting operations.

1.14.4 Risk analysis

HSH Entreprenør conducted a risk analysis for work operations relating to the project, dated 10 November 2016.

The risk analysis identifies '*plant and machinery colliding with pedestrians/cyclists while driving into/out of the building site'* as an element of very high risk (red). The following is described under '*actions*' to be taken to address this: *'SJA, clear rules on how to walk past plant and machinery. For deliveries of goods, a driver's mate shall accompany the driver when driving into/out of the site'*.

1.14.5 SJA

According to the contractor's HSE plan, an SJA shall be prepared for new and unfamiliar work operations, and for work at height with a high risk potential. The contractor prepared four SJAs in connection with the project: one dated 12 December 2016, one dated 12 February 2017 and two dated 17 February 2017.

Three of the SJAs are almost identical and were prepared for the activity *'Vehicles driving into/out of the school area for delivery of materials'* with the associated potential elements of risk/hazard *'Risk of collision with pedestrians/cyclists, as part of the access route will be via a cycleway/walkway'*. The associated risk-reducing action was described as '*A driver's mate shall always accompany the driver when vehicles are driven into/out of the site'*. No further risk-reducing measures, safety equipment or emergency preparedness were considered, as evidenced by the analyses.

The SJA dated 17 February 2017 was prepared for the activity *'Crane operations within the school area'*, with the associated potential risk/hazards of '*Crush injury, dropped load'*. The risk-reducing action was described as *'Cordon off the craning area. Never walk under the load'*, and safety measures/emergency preparedness were described as *'Cones and cordons'*.

It is clear from HSH Entreprenør AS's minutes of a meeting dated 1 December 2016 that the HSA Entreprenør AS prepared a general SJA for crane and traffic operations. Use of the walkway for access to the construction site is dealt with in the SJA dated 12 December 2016. In that analysis, the danger of collision with pedestrians/cyclists was identified and the proposed risk-reducing action was for the driver to be accompanied by a driver's mate when driving into/out of the building site.

The SJA includes a field for persons and undertakings involved in the planned work, and a signature field for those who have participated in the analysis. Nordic Crane Sør AS is not mentioned as being involved in the activity and the analysis has not been signed by the mobile crane driver.

HSH Entreprenør AS and Nordic Crane AS have informed the AIBN that the crane driver participated in the SJA prior to carrying out his first assignment, without signing the document.

1.14.6 Work notification plan

As mentioned above, the project had conducted risk analyses identifying transport into/out of the building site as an element of risk, but without preparing any work notification plan or associated signage plan and risk assessment for use of the walkway as an access route for vehicles to the building site.

1.15 Authorities, organisations and leadership

1.15.1 Kristiansand Municipality

The contracting client for the building project at Karuss School was Kristiansand Eiendom on behalf of Kristiansand Municipality. The walkway in question was also owned by Kristiansand Municipality, represented by the road, water and sewage section ('Ingeniørvesenet'), which was authorised to approve work notification plans in connection with road and roadside works. Both the above departments report to the Technical Sector.

Up until 2016, Kristiansand Municipality was also authorised to make administrative decisions on erecting and taking down certain traffic signs, including signs for regulation of walkways and cycleways. This authority has since been vested in the NPRA, Southern Region. The municipal authority can nonetheless collaborate with the police to prepare signage plans for the municipal road network, but these are subject to approval by the NPRA's signage authority.

1.15.2 HSH Entreprenør AS

HSH Entreprenør AS (HSH) is an independent company owned by HSH AS. It has approximately 60 employees and performs design and build contracts as well as individual building and construction assignments in the Agder counties.

HSH was contracted as design and build contractor for the 'Karuss School' project by Kristiansand Eiendom. HSH was responsible for the work to be carried out in connection with the project and HSH representatives coordinated the day-to-day work at the building site. HSH hired subcontractors for individual project assignments, including Nordic Crane Sør AS.

By agreement between HSH Entreprenør AS and Nordic Crane Sør AS the mobile crane was to arrive before 8:00 in the morning so that it could enter the site before the arrival of the students. The assignment was to be completed by 12:00 noon.

HSH would provide a driver's mate when Nordic Crane AS notified the crane's arrival, and the rigging plan specified a meeting point near Karuss Kindergarten. The mate had not yet turned up at the meeting point when the accident occurred, however.

1.15.3 Nordic Crane Sør AS

Nordic Crane Sør AS is an independent company owned by Crane Norway Group. The company was formed in 1999 and most of its activities take place in the Agder counties and the Sørlandet region of Southern Norway.

Nordic Crane Sør AS was hired by HSH Entreprenør AS to conduct lifting operations with a mobile crane at Karuss School on 7 March 2017. The crane company had conducted lifting operations for the same building project on two previous occasions using the same crane driver, mobile crane and meeting point.

On the day of the accident, Nordic Crane Sør AS assessed the driving conditions as being difficult, and they therefore deployed an additional driver's mate in order to assess the conditions and whether any particular measures were required. According to Nordic Crane Sør AS's procedures the crane driver was to carry out a safe job analysis (SJA) when the mobile crane arrived at the site where the work was to be performed, but there was no procedure that covered driving the crane to the site.

Nordic Crane Sør AS's follow-up and maintenance of the mobile crane in question are described in section 1.9.1.

1.15.4 Norwegian Labour Inspection Authority

The Labour Inspection Authority is a government agency that reports to the Ministry of Labour and Social Affairs. The agency is charged with conducting supervisory activities to ensure that enterprises comply with the requirements of the Act of 17 June 2005 No 62 relating to the working environment, working hours and employment protection etc. (the Working Environment Act). Certification bodies[6] are appointed by the Directorate of the Labour Inspection Authority in accordance with guidelines provided in the Regulations of 6 December 2011 No 1360 on administrative arrangements in the area covered by the Working Environment Act (Regulations on Administrative Arrangements). These certification bodies certify the enterprises of competence that carry out annual inspections of mobile cranes etc. classified as motorised equipment.

The Labour Inspection Authority's ordinary supervisory activities can include verification that the annual inspection has been conducted in accordance with the Regulations.

On a more general basis, the Labour Inspection Authority may conduct supervisory activities relating to the employer's maintenance and inspection of plant/machinery and working equipment, training of employees and other matters relating to safe use.

After the accident, the Labour Inspection Authority conducted supervisory activities in relation to Nordic Crane Sør AS, HSH AS and Kristiansand Municipality; see section 1.18.

1.15.5 Kolos Inspection AS

Kolos Inspection AS is a supplier of inspections, testing, modification, certification, maintenance, hire and sale of lifting equipment, established as part of the Kolos Group on 1 January 2016. Kolos Inspection AS conducted the most recent annual inspection of the mobile crane on 5 January 2017.

The company also conducts certified safety training in accordance with requirements and guidelines from the Labour Inspection Authority. The equipment portfolio includes a G1 mobile crane.

[6] The Directorate has approved six certification bodies.

1.15.6 KIWA Teknologisk Institutt Sertifisering as

KIWA Teknologisk Institutt Sertifisering as is one of six certification bodies appointed by the Labour Inspection Authority. The certification bodies follow up the certified enterprises of competence by conducting annual audits.

Certification of Kolos Inspection AS an enterprise of competence was carried out by KIWA Teknologisk Institutt Sertifisering as for one year at the time. KIWA Teknologisk Institutt Sertifisering issued a certificate on 18 May 2016 confirming that Kolos Inspection AS had documented and demonstrated that it had a management system that met the requirements in Section 8-1 of the Regulations on administrative arrangements.

The AIBN has also been informed that KIWA Teknologisk Institutt Sertifisering conducted an audit of Kolos Inspection AS on 20 September 2017, in which the mobile crane was used as a verification point. The report did not include any comments or nonconformities.

1.15.7 The NPRA

The NPRA is an administrative agency that reports to the Ministry of Transport and Communications. The agency is organised with two administrative levels: the Directorate of Public Roads and five regional offices. The NPRA is responsible for the planning, construction, operation and maintenance of European and national roads, and for approval and supervisory activities relating to vehicles and road users. The NPRA also prepares rules and guidelines for road design, operation and maintenance, road traffic, road user training and vehicles.

The NPRA approves all types of vehicles that require registration, and it approved the mobile crane when it was first registered. The agency is also responsible for approval and follow-up of private inspection bodies that carry out periodic roadworthiness tests of vehicles pursuant to the Act of 18 June 1965 No 4 relating to Road Traffic (Road Traffic Act).

The NPRA also serves as a signage authority. By signage authority is meant a body that is empowered to post and remove public traffic signs. Signage authority is provided for in the Regulations of 7 October 2005 No 1219 relating to public traffic signs, road markings, light signals and instructions (the Road Sign Regulations)

1.15.8 Official inspections and supervision of mobile cranes

1.15.8.1 *Periodic roadworthiness test according to the Road Traffic Act*

Mobile cranes registered after 15 September 2012 are classified as lorries under the Regulations of 5 July 2012 No 817 on the approval of road vehicles and road vehicle trailers (the Car Regulations). They are therefore subject to the requirements for annual inspections in accordance with the Regulations of 13 May 2009 No 591 relating to periodic roadworthiness tests of vehicles. Mobile cranes registered before 15 September 2012 are not subject to corresponding inspections. The items to be tested during the periodic roadworthiness test are described in the NPRA's joint instructions for periodic roadworthiness tests of vehicles, and all inspection bodies approved by the NPRA are required to comply with these instructions.

The mobile crane in question was registered as motorised equipment in 2006, and it was therefore not subject to the requirement for a roadworthiness test.

1.15.8.2 *Certified inspection of working equipment by an enterprise of competence in accordance with the Working Environment Act*

Mobile cranes are subject to a requirement for annual inspection by a certified enterprise of competence; see the Regulations No 1357 on execution of work, use of work equipment and related technical requirements (Regulations on the Execution of Work).

The annual inspections of category G1 mobile cranes are performed by enterprises of competence that have been certified by the inspection bodies, which are, in turn, appointed by the Labour Inspection Authority. These enterprises meet the requirements for organisation, quality assurance and inspection competence. Guidelines for the scope of inspection are described in a uniform normative document issued to all certified enterprises. This is currently being revised by the Labour Inspection Authority and the association of certification bodies ('Samarbeidsgruppen for sertifiseringsorgan' – SGS).

The annual inspection covers those parts of the working equipment that are important in relation to safety and the working environment and that are exposed to wear, cracking, damage, corrosion or similar. Inspections by enterprises of competence are largely based on the crane manufacturer's user instructions and pertaining inspection and maintenance information.

The certified enterprises of competence have no joint instructions or uniform checklists for the annual inspections, however, but prepare their own inspection forms based on various sources. The inspection forms form the basis for the certification of enterprises of competence.

An evaluation of the certification system by the Directorate for the Labour Inspection Authority in 2006 showed that a majority of the certified enterprises of competence requested a joint checklist with specification of the methods of inspection.

1.15.8.3 *Circular letter from certification body*

As one of six certification bodies, KIWA Teknologisk Institutt Sertifisering as (then known as 'TI sertifisering') sent a letter to its customers on 9 April 2010, concerning different practices relating to annual inspections of mobile cranes and other motorised equipment not subject to the requirements for periodic roadworthiness tests. The letter stated that, while some enterprises of competence inspected the vehicles' brakes, others limited themselves to inspecting the crane equipment. It went on to point out the need for more stringent inspections/procedures, and that the annual inspections suffered from inadequacies.

It was concluded in the letter that enterprises of competence must conduct brake tests on motorised equipment up until the Vehicle Regulations were amended, and that the certification bodies must collaborate and prepare instructions for brake tests in the interest of establishing uniform annual inspections. The letter went on to state the following:

> *Based on the above statement, we in TI Sertifisering request that all our customers and auditors start by preparing for the inclusion of special safety*

inspections of wheels/brake systems in inspections of motorised equipment that is not subject to periodic roadworthiness tests in accordance with EU requirements.

1.16 Acts, regulations and guidelines

The following acts of law, regulations and guidelines are of relevance to the accident (see the more detailed description in Annex F):

- The Act of 18 June 1965 No 4 relating to road traffic (the Road Traffic Act)
- The Regulations of 21 June No 747 relating to vehicular and pedestrian traffic (the Traffic Rules)
- Regulations of 7 October 2005 No 1219 relating to public traffic signs, road markings, light signals and instructions (the Road Sign Regulations)
- The NPRA's Handbook N301 *Work on and along roads*
- Regulations of 4 October 1994 No 918 on Technical Requirements for and Approval of Motor vehicles, Parts and Equipment (the Motor Vehicle Regulations)
- The Regulations of 5 July 2012 No 817 on the approval of road vehicles and road vehicle trailers (The Car Regulations)
- Regulations of 13 May 2009 No 591 relating to periodic roadworthiness tests
- Regulations of 25 January 1990 No 92 on the use of vehicles (Vehicle Use Regulations)
- Act of 21 June 1963 No 23 relating to roads (the Road Act)
- Act of 17 June No 62 relating to the working environment, working hours and employment protection etc. (the Working Environment Act)
- Regulations of 20 May 2009 No 544 on machinery (the Machinery Regulations)
- Regulations of 6 December 2011 No 1360 on administrative arrangements in the area covered by the Working Environment Act (Regulations on Administrative Arrangements)
- Regulations of 6 December 2011 No 1357 on execution of work, use of work equipment and related technical requirements (Regulations on the Execution of Work)
- Regulations of 3 August 2009 No 1028 relating to safety, health and working environment at building and construction sites (the Construction Client Regulations)
- Regulations of 6 December 2012 No 1127 relating to systematic health, environment and safety activities in enterprises (Internal Control Regulations)

1.17 Additional information

1.17.1 Accident involving a mobile crane at Smestad in Oslo in 2007

The AIBN has previously investigated an accident at Smestad in Oslo that occurred in 2007, in which a mobile crane collided with a private car and a motorbike (Report Road 2010/02).

The following is reproduced from the analysis part of that report:

> *In this connection, the AIBN is of the opinion that the Norwegian Labour Inspection Authority should place more emphasis on supervision of the maintenance systems of the companies in question. The Norwegian Public Roads Administration (NPRA) is responsible for the periodic roadworthiness tests and has extensive experience of inspecting heavy vehicles. The AIBN believes that more extensive cooperation between the Norwegian Labour Inspection Authority and the NPRA could contribute to greater safety in this area.*

Based on its findings, the AIBN submitted two safety recommendations. One of these was addressed to T.O. Bull AS:

> ***Safety recommendation ROAD No 2010/05T***
>
> *The investigation showed that several of the mobile crane's brake bands were worn down and that the braking effect was less than half of what the regulations required. T.O. Bull AS has not produced any documentation showing that the mobile crane's brakes were maintained as described in the mobile crane's lubrication and maintenance instructions, a condition for approval in the annual inspection by an enterprise of competence.*
>
> *The Accident Investigation Board Norway recommends that T.O. Bull AS improve its maintenance and documentation system so that the manufacturer's maintenance instructions are followed up.*

The above safety recommendation was closed by the Ministry of Transport and Communications on the following grounds:

> *Since 2007 T.O. Bull has been through a major audit of its maintenance and repair shop procedures, HSE/IC/QA etc. T.O. Bull AS holds follow-up courses for its drivers every six months, covering maintenance and prevention of damage/injuries as key topics. The case is closed.*

The other recommendation was addressed to the Norwegian Labour Inspection Authority.

> ***Safety recommendation ROAD No 2010/05T***
>
> *Mobile cranes and other motorised equipment permitted on public roads are not subject to requirements for periodic roadworthiness tests. Mobile cranes registered after a certain date will be subject to a requirement for periodic roadworthiness tests, but this will not have any retroactive effect. The Norwegian Labour Inspection Authority has not issued any guidelines for inspection of the vehicle part of motorised equipment during the annual inspection by an enterprise of competence, which means that inspection practice can vary.*

The Accident Investigation Board Norway recommends that the Norwegian Labour Inspection Authority collaborate with the Norwegian Public Roads Administration to implement measures to improve the safety of motorised equipment being driven on roads.

The above safety recommendation was closed by the Ministry of Transport and Communications on the following grounds:

In 2010, the Norwegian Labour Inspection Authority appointed a working group to prepare a checklist of items to be covered by inspections of working equipment. Inspection of brakes on mobile cranes will naturally be included on the checklist of items to be included in the annual inspections by enterprises of competence. Furthermore, the association of certification bodies will, in the form of a letter, make sure that there is no doubt about the requirement for brake testing and ensure that such tests are actually carried out. In addition to the above, the Norwegian Public Roads Administration will shortly be entering into an agreement with the Norwegian Labour Inspection Authority covering a related subject. The case is closed.

1.17.2 Notification of critical safety issue after the accident in Karussveien:

Based on the accident and with reference to the Regulations of 30 June 2006 No 793 on Public Investigation and Notification of Traffic Accidents etc., the AIBN found it necessary to inform the NPRA and the Labour Inspection Authority of the brake failure that was found in the mobile crane. The following is reproduced from the AIBN's letter of 5 May 2017 (see Annex D):

Based on our findings and assessments relating to these two accidents, the AIBN has chosen to issue a warning about the need for better follow-up of brake inspections of mobile cranes and similar motorised equipment used on roads. This applies in particular to procedures for the annual third-party inspections of mobile cranes registered before 2012.

1.17.3 Information received from the Labour Inspection Authority and the Directorate of Public Roads at meetings during the investigation

1.17.3.1 *Meeting of 27 April 2017*

The Labour Inspection Authority and the Directorate of Public Roads were represented by technical personnel and decision makers at this meeting at the AIBN. The AIBN presented the safety-critical findings it had made during its investigation and these were discussed. The meeting was followed up by the AIBN sending a notification of safety-critical issue relating to its findings to both agencies in a letter dated 5 May 2017 (see Annex D).

The Labour Inspection Authority and the Directorate of Public Roads confirmed that the safety recommendations submitted in Report Road 2010/02 had been closed, based on an intention to take appropriate action. No joint working group has been established for the two responsible agencies.

The Labour Inspection Authority had drawn attention to the problem in a meeting with the certification bodies, and the six certification bodies had conveyed the information to

their respective enterprises of competence in different ways. Hence it was not possible to measure the effect and the problem remained unresolved.

At the meeting, the AIBN learnt that, as of April 2017, 2,147 vehicles were classified as motorised equipment in the Motor Vehicle Registry, 877 of which were mobile cranes.

Mobile cranes registered after 15 September 2012 are classified as lorries and are subject to the NPRA's inspection regime. Mobile cranes registered before that date will be classified in the same category as before and will not be subject to periodic roadworthiness tests. It was a stated wish on the part of the NPRA and the Directorate of Public Roads that mobile cranes, and possibly all vehicles classified as motorised equipment, should be covered by the roadworthiness regime, but accomplishing this was seen as a more long-term task.

1.17.3.2 *Meeting of 10 January 2018*

The Labour Inspection Authority and the Directorate of Public Roads were represented at this meeting in the same way as at the meeting in April 2017.

The Labour Inspection Authority reported that it had conducted a supervisory survey of the certification bodies by post, which had shown that practice with respect to inspection of brakes was not uniform. According to the Labour Inspection Authority, a technical inspection of the vehicle part of a mobile crane requires the same level of expertise, equipment and acceptance criteria as a roadworthiness test, but many of the enterprises of competence lack these attributes. The Labour Inspection Authority therefore wanted vehicles registered as motorised equipment (i.e. work equipment subject to a requirement for annual inspection by an enterprise of competence) to be included in the roadworthiness regime.

The Directorate of Public Roads made it clear that technical inspections of the vehicle part the mobile crane came under the NPRA's area of responsibility and that, in the long run, older mobile cranes (registered motorised equipment) should be covered by the roadworthiness regime. The AIBN learnt that there were problems involved in carrying out roadworthiness tests of new mobile cranes due to their weights and dimensions, and that efforts are being made to resolve these problems. The Directorate of Public Roads discussed the possibility of basing the annual inspection by an enterprise of competence on a documented safety check. The Directorate also reported that the older mobile cranes registered as motorised equipment are not obliged to comply with signs indicating a roadside inspection, unless they are specifically pulled over.

The Directorate of Public Roads confirmed that, under Section 19 of the Road Traffic Act, the police or the NPRA's regional organisations have the authority to order inspections of motorised equipment.

1.17.4 Calculation of walkway friction conditions

As described in section 1.8 above, the results of the braking tests showed that the braking effect of the parking brake and service brake was defective on the second axle (i.e. the vehicle's parking brake was only effective on axle no 1). The vehicle was overloaded in relation to what was permitted, as described in the same section.

Based on information provided by Liebherr, the police and the NPRA, as well as the AIBN's own investigations, the AIBN has calculated whether the mobile crane would have started to slip had the parking brake been in accordance with the regulations and effective on both axles.

The friction coefficient cannot be determined accurately, but the AIBN's calculations show that a friction value of 0.29, as measured by the NPRA, would be sufficient to prevent the mobile crane from skidding, based on the actual gradient of 3º, the actual loads and with braking effect on the front axle only.

The calculations show that as long as the friction coefficient was greater than 0.17, the mobile crane would have been prevented from slipping given the actual loads. The calculations show that, had the mobile crane had satisfactory braking effect on axle no 2, it would not have started to slip as long as the friction coefficient was greater than 0.08.

While driving, heat develops in the tyres, and some of this heat will be transferred to the supporting surface when the vehicle is parked. It is very likely, therefore, that the friction conditions under the tyres were different from the surrounding friction conditions.

1.18 Implemented measures

1.18.1 Norwegian Labour Inspection Authority

1.18.1.1 *Supervision of the parties involved in the building project, after the accident*

After the accident, the Norwegian Labour Inspection Authority, Southern Norway has conducted supervisory activities in relation to Nordic Crane Sør AS, HSH Entreprenør AS and Kristiansand Municipality. The AIBN has obtained supervision reports and other documentation from the supervisory activities. The AIBN has assessed the Labour Inspection Authority's orders to the enterprises and used them as a factual basis in the case, together with own interviews and investigations.

Following supervisory activities in relation to Kristiansand Municipality and HSH Entreprenør AS on 22 March 2017, the Labour Inspection Authority did not issue any orders with reference to the measures implemented after the accident.

Supervisory activities in relation to Nordic Crane Sør AS on 27 March 2017 resulted in an order to provide crane drivers with specific training in the use of work equipment, and an order for inspection and systematic maintenance of work equipment.

1.18.1.2 *Supervision of the system for certification of enterprises of competence*

In spring 2017, the Labour Inspection Authority Mid-Norway conducted a supervisory survey of the designated certification bodies by post and carried out an on-site supervisory visit to one randomly selected enterprise of competence. The supervisory activities were concluded by sending a letter to the supervised bodies, in which the Labour Inspection Authority included the following clarification:

> *The Labour Inspection Authority points out that the certification body shall ensure that the enterprise of competence is qualified to carry out the inspections for which it is authorised. This includes whether the enterprise is technically qualified to assess whether it has sufficient competence of its own, or whether it*

should ask for part of the inspection to be conducted by another inspection body. The Labour Inspection Authority stresses that the certification body must also be able to verify that a certified enterprise of competence is actually fulfilling its role. The normative documents provide guidelines for the certification. This means that, as part of its practice, the certification body itself must prepare the criteria (attributes) for deciding whether a specific enterprise is qualified to carry out inspections of the type applied for. For the record, we also remind you of the following: The role of certification body confers an obligation to ensure that the certification body is staffed with personnel who are also able to make the technical inspection assessments needed for both approval and verification of the enterprise of competence's qualifications. In addition, the certification body must possess the resources needed to enable it to carry out technical tasks relating to certification, in a safe and proper manner. See Section 7-2 of the Regulations on administrative arrangements.

The supervisory activity that was conducted in relation to one enterprise of competence showed that the enterprise's inspection checklist required a brake test to have been carried out no more than 3 months beforehand, regardless of whether the mobile crane belonged to the category covered by the roadworthiness regime or not. The enterprise of competence did not approve use of a retardation meter alone.

1.18.2 The NPRA

The AIBN has not received any documentation of measures from the NPRA.

1.18.3 Kristiansand Municipality

After the accident, Kristiansand Eiendom, on behalf of Kristiansand Municipality, has reviewed and evaluated the municipality's procedures internally and together with partners. Specific measures were implemented in connection with driving into/out of the building site as described below, including the following changes/supplements to procedures:

- A plan was drawn up, with the contractor, showing where incoming vehicles/deliveries were to stop before entering the building site. The plan was to be distributed to all suppliers delivering by vehicle, before commencement of the delivery, and a signed safe job analysis (SJA) was to be enclosed.

- The project introduced a measure whereby the SJA for the relevant work operation must be signed for every vehicular delivery to the building site.

- All incoming delivery vehicles should be met and accompanied by a representative of the main contractor and/or the client (wearing visibility clothing) when entering the building site.

- When driving on a walkway or in other areas used by pedestrians/cyclists, however, consideration should be given to cordoning off the area.

- Under demanding/challenging weather/driving conditions, snow clearance/sanding/salting etc. was to be carried out before the vehicular movement took place.

- A schedule was prepared of the times when vehicle movements into/out of the building site could take place.

1.18.4 HSH Entreprenør AS

Approximately one week after the accident, HSH Entreprenør AS conducted a new SJA for vehicle transport to/from the Karuss School, of which the following is cited here:

- It specified that the safety representative/foreman was to be notified of the arrival and that the driver should wait at the meeting point until a driver's mate arrived. The meeting point was stated to be by the parking lot after passing Karuss Kindergarten.

- A watch was also to be posted at the crossroads by the underpass at the bottom of the walkway.

- A timetable of red and green time zones was prepared, where driving up until 7:30 in the morning was marked in green, while driving between 7:30 and 9:00 was marked in red. Other red zones were specified during school breaks and at the end of the school day.

1.18.5 Nordic Crane Sør AS

Based on an internal review after the accident, Nordic Crane decided and implemented the following measures:

- The company established a new position, with responsibility for the following:
    - Follow-up of plant/machinery transport, including the status of plant/machinery and implementation of measures as necessary.
    - Follow-up of service of machinery/plant, including execution of necessary service operations.
    - Follow-up of machinery/plant documentation.
    - Maintenance of machinery/plant, including first-line maintenance together with the crane driver and follow-up of contracted maintenance work.
    - Follow-up of annual certification.
- More internal control:
    - Half-yearly inspection of brakes on all cranes.
    - Brake tests of cranes by external repair shops.
- Revision of routines and procedures:
    - Procedure prepared for simple brake test along a marked section.
    - Points arising from pre-assignment inspections to be addressed in the SJA for transport to the building site.

- Information about and lessons learnt in connection with the incident has been shared with Nordic Crane's sister companies.

- The sister companies cooperate to improve their inspections of cranes and equipment.

1.18.6 Kolos Inspection AS

Kolos Inspection has implemented the following measures after the accident:

- Inspectors have attended refresher courses/been retrained.

- Brakes are inspected on site.

- The inspection checklists now include a point whereby a roadworthiness test of the brakes, or retardation measurements, must have been carried out no more than one month prior to the inspection.

- If the crane owner is unable to document the above-mentioned tests, this will be noted as a nonconformity during the inspection that the crane owner is required to rectify.

- Kolos Inspection AS has bought a retardation meter and offers to conduct retardation measurements for its customers.

2. ANALYSIS

2.1 Introduction

The AIBN has assessed the severity of the accident and the sequence of events. On the basis that the mobile crane was occupying a pedestrian walkway when the five-year old boy was fatally injured and three other people were injured, the AIBN found that there was a particular reason to conduct a safety investigation of the accident.

The analysis start with an assessment of the sequence of events. Then the mobile crane's movements on the walkway and the mobile crane's reduced braking power are considered. The use, maintenance and inspection systems that can throw light on how this condition could arise and be allowed to develop in the mobile crane, and why it was not discovered at an earlier time will also be analysed. Finally assessments and measures relating to adaptation and use of the walkway as an access route for the mobile crane, and the fact that the walkway was not signposted as a walkway and cycleway will be discussed.

The parties involved are referred to by their respective roles rather than by name, so as to better illustrate the processes and interaction that were of consequence for safety. Public authorities are referred to by name.

The investigation and analysis were conducted in line with the AIBN's framework and analysis process for systematic safety investigations (the AIBN method).

2.2 Assessment of the sequence of events

The crane driver chose to reverse the mobile crane onto the walkway and felt that the road grip was sufficient to stop the crane. He parked temporarily and left the driver's cabin to assess the driving conditions on the walkway, which was covered in snow and ice. He was assisted by a colleague/driver's mate from the same company. This shows that the crane company and the crane driver had identified the risk associated with using the walkway, and that the driving conditions were such that they wanted to assess the need for using tyre chains. The main contractor had assigned a person to meet the mobile crane, but he had not yet arrived. The investigation has shown that there was some uncertainty regarding the exact meeting point and communication concerning the meeting point.

At that time, the crane driver had no indication that there was anything wrong with the brake system. When the mobile crane unexpectedly started to move down the walkway, the crane driver tried unsuccessfully to climb into the driver's cabin. The driver's mate observed the pedestrians who were on collision course behind the mobile crane and ran towards them to warn them and try to bring them to safety. These actions show that both the crane driver and the driver's mate were quick to perceive the dangers involved in the situation and tried to prevent and reduce the consequences. The mobile crane skidded/rolled uncontrolledly downhill at increasing speed as the slope became steeper.

The three pedestrians and the driver's mate were all hit by the mobile crane as it continued down the walkway. Its movement was limited by the railings on one side of the walkway and by the adjacent terrain on the other, and the mobile crane finally came to rest up against a rocky outcrop. All four ended up behind and partly under the mobile

crane, but the driver's mate quickly managed to get out. He immediately tried to free the other pedestrians, while the five-year-old boy remained trapped under the mobile crane.

Witnesses, rescue personnel and several others arrived and helped to free the boy. He was critically injured, however, and subsequently died in hospital as a consequence of his injuries. The AIBN believes that all those involved did all that was possible to reduce the scope of injuries.

2.3 The mobile crane's movement down the walkway

There was not enough friction on the snow-covered walkway for the parking brake to keep the mobile crane from moving downhill, given the gradient of the slope and that the braking power was only effective on the first axle. The AIBN's investigations and calculations show that, had the road been bare and the friction conditions better, and/or had the parking brake transferred braking power to the second axle (as it was designed to do), the mobile crane would probably have remained at a standstill. The crane started to slip shortly after the driver left the driver's cabin; exactly how long afterwards is impossible to ascertain.

The NPRA measured a friction coefficient of 0.29 between the tyres and the supporting walkway surface. The AIBN is aware that the retardation measurements were carried out using a different vehicle with different tyres and loads from those of the mobile crane. The AIBN therefore has doubts about the relevance of the measured friction value.

The actual friction between the tyres and the supporting surface may have changed between the time that the mobile crane was parked and the time it started to slip. The background to this is that the heat that develops in the tyres, while the crane is being driven, is transferred to the supporting surface and this changes the friction between the tyres and the surface. The result is often a lower friction coefficient, and the front axle's capacity to keep the mobile crane from moving will be gradually reduced. The greatest element of uncertainty in the AIBN's calculations is how the friction characteristics changed after the mobile crane was temporarily parked.

The AIBN believes that the mobile crane started to slip as a consequence of several factors: the changed friction characteristics between the tyres and supporting surface, the lack of braking effect on the second axle and the load distribution. The calculations showed that the lack of braking effect on the second axle and the change in friction were the main contributors that caused the mobile crane to start skidding. The AIBN believes that the overload had little bearing on the incident.

2.4 Brake failure in the mobile crane

2.4.1 Assessment of the brake failure based on technical examinations

Throughout the investigation, the AIBN has focused on how the brake failure could develop without such a safety nonconformity being detected by the crane owner or coming to light during the annual inspection by an enterprise of competence.

The traces of load exposure on the brake components are evidence of long strokes in the wheel brake system on axle no 2. Based on findings and analyses, the most probable explanation is that the rollers have passed over the highest point on the wedge bolt during braking. The return springs on the brake shoes are more powerful than the return springs

in the expander assembly, so that the components are held permanently in this position without the crane operator being warned. Another possibility is that the 'rollers' in the expander assembly had somehow 'hooked' onto the inside of the wheel brake system.

The investigation has shown that there were marks at the bottom of the self-adjusting mechanism. That suggests that the function was not active and hence failed to compensate for brake band wear. This problem is also described in Annex B and the workshop literature issued by the brake manufacturer.

All in all, the AIBN finds that the braking power has deteriorated gradually over a period of time as a result of wear. The grounds for this view are described in more detail in the following section.

2.4.2 Brake repairs and maintenance

The AIBN has not received any documentation showing when, or by whom, maintenance of and/or repairs to the brakes on axle no 2 were carried out. Based on the marking on the brake components on the left side, it is probable that it took place no more than four years prior to the accident.

The AIBN has assessed the mounting of the brake components in relation to the manufacturer's instructions and setpoint values. Nonetheless, it has not been possible to prove that the pistons in the wheel cylinders were adjusted to the set point values as indicated (see Annex B) when last repaired. The AIBN is therefore unable to conclude that there was any reduced braking power (long strokes) immediately after the most recent repairs as a result of incorrect adjustment, but the possibility cannot be excluded.

The investigation has shown, however, that the self-adjusting function only worked within a certain 'working range'. If the wheel cylinders' configurations are outside this working range, the self-adjusting function is incapable of compensating for brake band wear as it is designed to do. After a while, the clearance between the brake band and drum becomes so wide that the rollers that transfer load weights during braking slide across the top of the expander assembly. This means that the braking power will eventually be lost without the crane operator being warned.

The explanation given by the brake and crane manufacturers for the brake failure, as described in the service notices (annexes B and E), is that the rollers on the expander assembly may have hooked onto the bottom side of the pistons. In the AIBN's opinion, this is not possible. The AIBN therefore carried out own examinations to determine what factors contributed to the loss of braking power in the brakes on the second axle as described in the previous section.

The AIBN believes that the design of the wedge brake system in question is vulnerable in that it is possible to mount it in a way whereby the self-adjusting mechanism will not work. The AIBN also finds it censurable that wheel brake system movements can cause displacement of important brake components, and thus loss of braking power without the crane operator being warned. This safety problem has been communicated to the brake component manufacturer in Germany.

The crane manufacturer's maintenance instructions point to the need for regular inspection and maintenance in order to ensure safety. It is also emphasised that the braking action must be checked after repairs to the brake system. Annex A also includes

the crane manufacturer's description of recommended service intervals. The AIBN believes that potential brake failure can be detected by complying with these procedures.

Maintenance of the mobile crane's brakes requires both skills and familiarity with the brake system on the part of personnel, and that necessary equipment for such work is available. The wheel brake system is a 'closed' system, so that inspection of the condition of the brakes (brake band, clearance and any slackness in the brake shoes) must be carried out through the inspection hatches in the brake shields. The AIBN is therefore of the view that two persons are required in order to carry out function tests in accordance with the manufacturer's maintenance instructions.

The AIBN finds that the brake failure most probably occurred gradually after repairs/maintenance were most recently carried out on the wheel brake. The investigation has shown that this was not detected during the company's maintenance and self-inspections. Similar failure is also discussed in a previous AIBN report (see section 1.17.1). Based on what is discussed above, the AIBN emphasises the importance of follow-up by the crane owner to ensure proper maintenance of the mobile crane's brake system.

2.5 Use, maintenance and internal control of the mobile crane

2.5.1 Introduction

The AIBN has assessed the crane owner’s practice and procedures for use and follow-up of the mobile crane. We start by analysing the crane driver's responsibility and tasks. We then go on to analyse systematic maintenance as a part of the company's internal control system, including mandatory self-inspection by the company, in contrast to certified third-party inspection by an enterprise of competence.

2.5.2 Daily checks and reporting

The crane owner had a practice whereby the crane driver was responsible for the daily/weekly checks of the vehicle. The crane driver stated that he did not notice anything out of the ordinary while driving/parking the mobile crane in question. This can be explained by the fact that there was braking effect on two axles, and that it would therefore not be easy to detect the reduced braking effect during ordinary braking (moderate retardation). Nor would it be easy for the driver to detect that the parking brake failed to be effective on one axle without testing this on a slope of a certain gradient. The measure implemented by the company whereby a simple test of the service and parking brakes will be carried out along a marked section will, in the AIBN's opinion, enable detection of any weaknesses in the braking effect.

2.5.3 Systematic maintenance and inspection

The accident has shown that the crane owner, prior to the accident, did not have adequate procedures for brake inspection/testing; see the crane manufacturer’s maintenance instructions. The crane owner did not have its own approved repair shop in Kristiansand; according to the information provided, expert services were procured from a sister company in Stavanger or from external repair shops when needed. The AIBN finds that, even if the crane owner bought this maintenance service, there is nonetheless a requirement for systematic follow-up of maintenance through reporting and execution.

According to the Regulations on Execution of Work, maintenance of work equipment must include regular inspection of components that deteriorate as they are used, i.e. not just preventive lubrication and replacement of wear components. Self-inspection by the company shall be an addition to the annual inspection by an approved certified enterprise of competence. The persons who are to carry out such inspections need sufficient training and practice as well as instructions on how it should be done. At the time of the accident, the crane owner had no such competent persons.

The crane owner was unable to document that there had been any systematic inspections and reporting in connection with day-to-day use of the mobile crane. Nor was the company able to document any systematic follow-up of findings made during those inspections that were actually carried out.

One of the findings in the investigations was that, on the day of the accident, the mobile crane was carrying heavy counterweights, so that the actual total weight of the vehicle exceeded the authorised total weight. This is in breach of the Regulations and indicates that the safety of the transport assignment was not adequately followed up.

After the accident, the crane owner has made several changes and has documented the measures implemented (see section 1.18.5) to improve the situation and prevent accidents in connection with the use of mobile cranes. Measures include closer follow-up and documentation of service/maintenance, exchange of experience and lessons learnt between the sister companies in the Crane Norway Group. Furthermore, documentation of a pre-assignment inspection is now used as a basis for the SJA that is conducted before commencing the work.

The AIBN believes that the systematic follow-up measures implemented by the crane owner after the accident will be capable of contributing to early detection of any break failure.

In this as in previous investigations, the AIBN found that many companies rely on the annual official inspection and fail to address safety through adequate self-inspection of vehicles. This is discussed in more detail in section 2.6.

2.6 Official inspections and supervision of mobile cranes

2.6.1 Introduction

The investigation showed that there has been inadequate follow-up of the roadworthiness of mobile cranes. Both the Labour Inspection Authority and the NPRA have the legal authority to address this.

The AIBN has previously investigated an accident with a mobile crane that collided with a private car and a motorbike at Smestad in Oslo in 2007 (Report Road 2010/02). The findings included brake failure and inadequate inspection procedures. In that connection, a safety recommendation was submitted to the Labour Inspection Authority and the NPRA pointing out the need to improve the safety of motorised equipment being driven on roads.

The safety recommendation was closed based on intended follow-up by the Labour Inspection Authority by including brakes on the list of items to be inspected, and a letter from the association of certification bodies that would clarify the requirements for brake

tests and ensure that such tests were carried out. In addition, the NPRA and the Labour Inspection Authority were to sign a cooperation agreement relating to this area. The NPRA did not implement any measures of its own.

The AIBN found that the previously submitted safety recommendation had not been adequately followed up and considered that this was critical to safety. In May 2017, the AIBN therefore issued a Notification of a critical safety issue to the two agencies.

The AIBN has based its further analysis on both the accident at Smestad in Oslo and the most recent accident at Karuss School in Kristiansand.

2.6.2 Periodic roadworthiness test

The NPRA has the authority to carry out roadworthiness tests of mobile cranes registered after 15 September 2012, since these are classified as lorries under the Car Regulations. The AIBN appreciates that such tests are conducted by approved inspection bodies in accordance with common and uniform inspection instructions.

However, mobile cranes (motorised equipment) like the one involved in the present accident that were registered prior to 15 September 2012 are still not covered by the roadworthiness regime. The AIBN has been informed that these cranes have also not been brought under the scope of the regime during revisions of the Regulations on Periodic Vehicle Inspections, and that this must be a long-term measure.

There are challenges involved in testing large mobile cranes – vehicle dimensions, several drive axles and large wheel diameters that sometimes make roller brake testing impossible. This means that alternative inspection methods described in the inspection instructions must be used. The NPRA has informed the AIBN that it will consider applying the whole roadworthiness regime to all mobile cranes and motorised equipment, and possibly also consider use of a mobile inspection body for this vehicle category, given that geographical distances and road design pose challenges.

The situation will improve as older mobile cranes are being phased out. The AIBN does not consider this to be satisfactory from a safety perspective, however, given the heavy weight and dimensions of these vehicles. They represent a great threat to road safety in the event of brake failure, and the AIBN is of the opinion that the NPRA should contribute with increased inspection activity or other measures to improve safety.

2.6.3 Inspection of the mobile crane by certified enterprise of competence

The annual inspections in 2016 and in January 2017 were carried out by two different enterprises of competence. The investigation has shown that none of these inspections included tests of the braking effect. The annual inspections are carried out using checklists that are based on a 'normative scope of inspection', which is the same for all certified enterprises of competence. Each enterprise has developed its own practice through use of its own checklists, which can give rise to differences in how they handle inspection and testing of brakes.

The AIBN's interviews with several certification bodies and certified enterprises of competence, and input received from individual players in the crane sector, show that there is a unanimous wish for joint checklists and specifications for the annual inspections by enterprises of competence. Another challenge has proved to be that many

crane owners want the annual inspection to be conducted in January or at the earliest possible time of year, in order to extend the interval before the subsequent inspection becomes mandatory, as the inspection interval is regulated by calendar year and not by month.

Winter is also a time of year when brake testing in an appropriate area can be difficult and this may contribute to the inspections not including brake testing. A similar challenge is stated to be that many cranes are rigged at a construction site and in operation when it is time for inspection.

In spring 2017, the Labour Inspection Authority conducted a supervisory survey by post of the six designated certification bodies for enterprises of competence, with reference to the notification of a critical safety issue that the authorities had received from the AIBN. The results of these supervisory activities showed variations in the practice for following up the certified enterprises with respect to brake testing (there was no mention of other technical driving equipment such as the steering system etc.).

After the accident, the enterprise of competence has implemented several measures that the AIBN finds appropriate to detecting critical safety defects during the annual inspection. Based on the measures initiated by the enterprise of competence, the AIBN believes that the annual inspections will be better able to meet the sector's expectations of the inspection system, and, as a third party, the enterprise of competence will also require documentation of brake maintenance and testing produced by the crane owner. It is left to the certification bodies and the Labour Inspection Authority, however, to build on the good practice of one certified enterprise and raise the practice of the remaining enterprises of competence to the same level.

2.6.4 Overall assessment of official inspections and supervision

The investigation has shown that uniform inspections of the vehicle part of mobile cranes (motorised equipment) are still not included in inspections by certified enterprises of competence supervised by the Labour Inspection Authority.

The AIBN takes a favourable view of the fact that uniform and extensive brake system testing is included in inspections of new mobile cranes under the supervision of the NPRA, and is of the opinion that this regime should also cover older mobile cranes.

Based on the previous and present investigations, the AIBN finds that leaving the condition of the brakes in mobile cranes to chance is a serious matter, given the general public's expectations that such heavy machinery is inspected and kept in a roadworthy condition. The investigation has shown that the crane sector and owners of such heavy vehicles also expect the same level of safety to apply regardless of whether a mobile crane is registered as motorised equipment or a lorry, a view that the AIBN supports. The AIBN believes that there is a risk of further accidents, even if the level of exposure is relatively low.

The investigation has made it clear that both expertise and equipment are needed to conduct roadworthiness tests of motorised equipment. In the AIBN's opinion, the NPRA should contribute more expertise, so that the road safety of mobile cranes does not depend on what inspection regime they are subject to. The AIBN supports the view of the competent authorities that all registered motorised equipment should come under the roadworthiness regime in the long run.

The Labour Inspection Authority's system of inspections by certified enterprises of competence is intended to ensure the safe use of mobile cranes. The NPRA is responsible for the approval of registered mobile cranes (motorised equipment) and for supervising that the vehicles are in the prescribed condition. The AIBN is of the opinion that the NPRA should help ensure adequate attention to road safety during the annual third-party inspections that are subject to the Labour Inspection Authority's regulations. The investigation has shown that the annual inspections by enterprises of competence are not uniform and do not meet the sector's expectations as regards attention to road safety.

The AIBN submits two safety recommendations on this point.

2.7 Use of the walkway as access route to a building site

No signs had been posted to show that the walkway was being used for access to the building site, and the building project had not taken any action to prevent pedestrians from using the walkway while the mobile crane was entering the building site at Karuss School. The main contractor had a man on the ready to receive the mobile crane on arrival, but when the mobile crane accidentally started to move, he had not yet reached the walkway where it had stopped.

Use of a walkway/cycleway as an access route to a building site heightens the risk of coming into conflict with pedestrians. Assessment, notification and proper securing of the area are therefore important in connection with work involving use of walkways/cycleways, so that all affected parties are clearly warned and protected against any hazards.

Kristiansand Municipality and the main contractor have told the AIBN that notification and securing of the work site are used, where work is being carried out on or close to walkways/cycleways. This is not done, however, when a walkway/cycleway is used for access to building sites or work sites for limited periods. Hence, the walkway where the accident occurred was not signposted or secured, other than that a mate was to walk ahead of the mobile crane down the walkway.

The AIBN knows that Karuss School had concerns about safety. The HSE plan for the project did not mention access to the building site as *'work that could put human life or health at risk'*.

In the AIBN's opinion, a work notification plan should have been prepared for the activity on the walkway in connection with the building project. The Road Sign Regulations and Working Environment Act contain stringent requirements for planning, notification/warning signs and risk assessment of such activity, and the AIBN considers the absence of an approved work notification plan in connection with the work to be a serious matter. The AIBN is also of the opinion that, in its capacity as client, Kristiansand Municipality should identify the need for such a plan as early as during the preparation of the HSE plan for the project and should include an approved work notification plan as a criterion and follow-up item when ordering the assignment from the main contractor. Furthermore, in the AIBN's opinion, the main contractor should also identify the need for a work notification plan when planning the project, particularly when the plan proposes use of the walkway/cycleway as an access route to the building site.

The process of preparing and approving a work notification plan, including a risk assessment and a signage plan, must, in turn, involve the municipal signage authority and

road traffic experts. Such an approval process will also entail notifying the affected parties, in our case Karuss School and Karuss Kindergarten, of the intended use of the walkway as access route. Furthermore, the process will enable identification and implementation of compensatory measures to follow up elements of risk such as the risk of collision with pedestrians/cyclists, friction, the slope of the walkway and the kindergarten and school's opening hours.

The AIBN submits one safety recommendation to Kristiansand Municipality on this point.

2.8 Failure to post signs by the walkway

Use of the walkway was not regulated by any signs, such as for example sign no 518 'Walkway' or sign no 522 'Walkway and cycleway'. In the municipal zoning plan, however, the walkway is defined for use by pedestrians. In Section 1 of the Traffic Rules, a 'footpath and cycle track' is defined as: *'Any path or track designated by an official traffic sign for the use of pedestrians or cyclists or a combination of pedestrian and bicycle traffic.'*

The AIBN has been informed by the municipality that it has no fixed practice of signposting all walkways and cycleways that it owns. The municipality is of the opinion that walkways and cycleways, through their design and geometry, clearly signal to other road users that they are not for use by motor vehicles.

In its investigation, the AIBN has not received any information to suggest that anybody had misunderstood the walkway status of the path, even if it was not signposted. The AIBN finds that this was not a safety problem in connection with the present accident. Nonetheless, the AIBN has doubts about the municipality's practice, particularly when seen in the light of regulatory requirements.

2.9 Other findings – The crane manufacturer's maintenance instructions

In section 1.9.2.1, the AIBN cited excerpts from the crane manufacturer Liebherr's maintenance instructions in Annex A, of which the following sentence is reproduced here:

> *The braking function can be checked through the observation holes in the wheel caps.*[7]

The AIBN finds that it is incorrect to say that the braking function can be checked through *'the observation holes in the wheel caps'*, which are mounted on the outer of the wheels. In the AIBN's opinion such a check must be carried out through the inspection hatches on the brake shields. These are located on the inner side of the wheels and the inspection cannot be carried out from the outside of the vehicle.

The AIBN asks the crane importer to note that the technical terminology used in the translation is inaccurate.

[7] This is how the instructions were translated into Norwegian.

3. CONCLUSION

3.1 Specific results of the investigation

The investigation has shown that no work notification plan had been prepared for the project. Hence, no signs had been posted to show that the walkway was being used for access to the building site, and the building project had not taken any action to prevent pedestrians from using the walkway while the mobile crane was entering the building site at Karuss School.

The investigation has shown that there was a serious fault in the mobile crane's brake system, and that this had not been detected through maintenance and self-inspection by the crane company. Nor had it been detected during the official inspection approximately two months prior to the accident.

Mobile cranes that were registered before 15 September 2012 are exempt from the requirement for periodic roadworthiness tests, and the certified inspections by enterprises of competence are not subject to uniform guidelines for inspection of brakes.

In this as in previous investigations, the AIBN found that many companies rely on the annual official inspection and fail to address road safety through adequate self-inspection of vehicles.

3.2 The chain of events, operational and technical factors

a) The mobile crane's service and parking brakes were not effective on the second axle.

b) The front wheels were blocked by the parking brake, while the wheels on the second and third axle turned freely.

c) The mobile crane started to skid/roll uncontrolledly down the walkway.

d) The mobile crane was overloaded by 7.6 tonnes.

e) The mobile crane started to skid as a consequence of several factors: changed friction characteristics between the tyres and supporting surface and lack of braking effect on the second axle. The overload had little bearing on the incident.

f) The crane driver had not noticed anything out of the ordinary in the brake system while driving.

g) The crane driver stopped the mobile crane on relatively level ground at the top of the slope, engaged the parking brake, and left the driver's cabin together with the driver's mate to assess the driving conditions and whether tyre chains were needed.

h) Where the mobile crane had stopped, the walkway was covered in snow and ice, and it had not been salted or sanded. The steep hill that branches off from the walkway network and continues up towards the school had been salted, however, and was partly free for snow.

i) The braking power on the front axle was not sufficient to prevent the heavy mobile crane from skidding, given that the tires had limited road grip.

j) All parties involved did everything that could possibly be expected to reduce the scope of injuries in connection with the loss of control of the mobile crane.

3.3 Underlying factors

a) The braking effect had probably deteriorated over a period of time, probably because the self-adjusting mechanism was outside its working range.

b) The design of the wedge brake system is vulnerable in that it is possible to mount it in a way whereby the self-adjusting mechanism will not work.

c) Long strokes in the wheel brake system can cause displacement of important brake components, and thus loss of braking power without the crane operator being warned.

d) The wheel brake system is a 'closed' system, so that inspection of the condition of the brakes (brake band, clearance and any slackness in the brake shoes) must be carried out through the inspection hatches in the brake shields. Inspections require skills and qualifications relating to this type of brake system.

e) The employer/crane owner lacked written procedures for inspection of the brakes.

f) The company had inadequate documentation of maintenance of the vehicle part of the mobile crane and had failed to follow up inspection points from previous inspections in a systematic manner.

g) Braking tests had not been performed during inspections of the mobile crane by enterprises of competence, as expected by the crane owner.

h) The investigation has shown that enterprises of competence, the crane sector and owners consider there should be joint checklists and descriptions for annual inspection of the vehicle part of mobile cranes.

i) The Norwegian Labour Inspection Authority and the NPRA had failed to adequately follow up the AIBN's previous safety recommendations relating to inadequate inspection of brakes on mobile cranes.

j) The crane company had no documented risk assessment of safe access to the building site for the mobile crane.

k) The project did not pay adequate attention to the safety of pedestrians who used the walkway.

l) The Road Sign Regulations and the Working Environment Act contain requirements for planning, notification/warning signs and risk assessment of such activity.

m) No work notification plan was prepared for use of the walkway for access to the building site.

4. SAFETY RECOMMENDATIONS

The investigation of this accident has identified several areas in which the AIBN deems it necessary to submit safety recommendations for the purpose of improving road safety.[8]

Safety recommendation ROAD No 2018/01T

The accident outside Karuss Kindergarten and School in Kristiansand on 7 March 2017 occurred on a pedestrian walkway, at a time when children and families were on their way to school/ kindergarten. A child died in the accident. The walkway was being used as an access route to the building site during the renovation of a primary school. The investigation has shown that Kristiansand Municipality, being the client, failed to identify the need to include a work notification plan in the health, safety and working environment (HSE) plan for the project. The AIBN believes that a work notification plan and related risk assessments would have been capable of identifying potential conflicts between vehicles and pedestrians/cyclists, and ensuring the posting of appropriate signs and proper adaptation of the access route.

The Accident Investigation Board Norway recommends that Kristiansand Municipality implement procedures to ensure road safety by requiring that work notification plans be prepared in connection with municipal building works that affect public roads.

Safety recommendation ROAD No 2018/02T

The accident outside Karuss kindergarten and school in Kristiansand on 7 March 2017 claimed the life of a child who became trapped under a mobile crane with inadequate braking power. The official inspection of the mobile crane had not been able to identify these defects. The mobile crane was initially registered in 2006 and was thus exempt from the Road Traffic Act's requirement for periodic roadworthiness tests. Pursuant to Section 13-1 of the Regulations on the Execution of Work, mobile cranes and other work equipment are subject to a requirement for certified inspection by an enterprise of competence. The AIBN's investigation has shown that the inspection regime does not include unambiguous guidelines for the inspection of brakes and other technical driving equipment.

The Accident Investigation Board Norway recommends that the Norwegian Labour Inspection Authority, in its capacity as supervisory body, ensures that inspections by enterprises of competence of brake systems on mobile cranes and other plant and machinery not subject to periodic roadworthiness tests are carried out in a uniform manner and so as to ensure an adequate level of road safety.

Safety recommendation ROAD No 2018/03T

The accident outside Karuss kindergarten and school in Kristiansand on 7 March 2017 claimed the life of a child who became trapped under a mobile crane with inadequate braking power. The official inspection of the mobile crane had not been capable of identifying these defects. Mobile cranes that were registered before 15 September 2012 are exempt from the requirement for periodic roadworthiness tests, and the certified inspections by enterprises of competence are not subject to uniform guidelines for inspection of brake systems.

[8] The investigation report is submitted to the Ministry of Transport and Communications, which will take necessary steps to ensure that due consideration is given to the safety recommendations, cf. Section 14 of the Regulations of 30 June 2005 on Public Investigation and Notification of Traffic Accidents etc.

The Accident Investigation Board Norway recommends that the Norwegian Public Roads Administration initiate measures to ensure that all registered mobile cranes, plant and machinery used on roads are subject to uniform brake system inspections.

Accident Investigation Board Norway

Lillestrøm, 19 March 2018

REFERENCES

AIBN (2010). Report Road 2010/02

ANNEXES

Annex A: Excerpts from the crane manufacturer's maintenance instructions, original English version

Annex B: Service notice from the crane manufacturer Liebherr

Annex C: Excerpts from the NPRA's 'Work on and along roads' N301

Annex D: Notification of critical safety issue to the Norwegian Labour Inspection Authority and the Norwegian Public Roads Administration

Annex E: Service notice from the brake manufacturer Wabco

Annex F: Excerpts from acts, regulations and guidelines

7.02 MAINTENANCE INTERVALS ON CRANE CHASSIS 026282 01

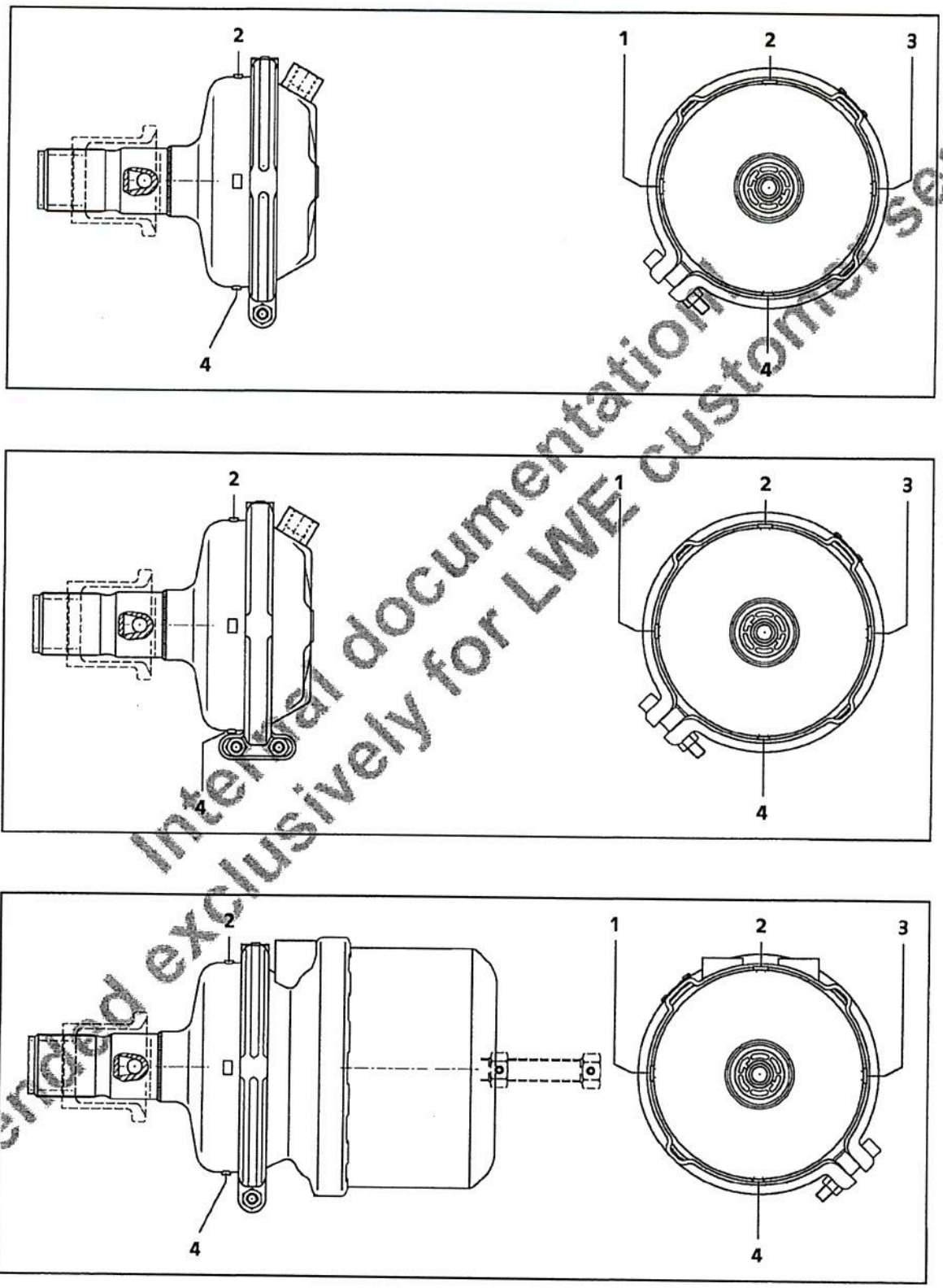
	First maintenance after	Regular maintenance every			Minimum maintenance annually	Inspections	
		250 hr. 5000 km	500 hr. 10000 km	1000 hr. 20000 km		daily	weekly
□ **Electrical system**							
- Check vehicle lighting system for function						×	
- Check cable connections and battery acid level					× *		
□ **Fuel system**							
- Check for leaks						×	
- Check condition and mounting			×		×		
- Drain off water and sediments			×		×		
- Clean pre-filter for fuel auxiliary pump			×		×		
- Check fuel preliminary filter, drain off water if necessary		every 50 hrs.					
- Replace fuel preliminary filter				×			
□ **Tires**							
- Check lug nut tightness, tighten if necessary	100 km	×					
- Check tire pressure							×
□ **Brake system**							
- Check brake system					×		
- Check brake pad thickness		×					
- Adjust brakes, if necessary, replace brake pads		×					
- Check brake disks		×					
- Check brake drums		×					
- Check function of parking brake and service brake						×	
□ **Eddy current retarder**							
Check mechanical and electric parts (Observe manufacturer's guidelines)	5000 km		×				

* in hot regions 2 × per year

7.02 MAINTENANCE INTERVALS ON CRANE CHASSIS 026282 01

	First maintenance after	Regular maintenance every			Minimum maintenance annually	Inspections	
		250 hr. 5000 km	500 hr. 10000 km	1000 hr. 20000 km		daily	weekly
□ **Air pressure system**							
- Check for leaks							×
- Check operating pressure of brake system						×	
- Check shut off pressure						×	
- Drain moisture from air pressure tank					×		
- Replace air dryer granule elements					×		
- Clean prefilter air dryer					×		
□ **Driver's cab**							
- Check armatures / instruments for function						×	
- Check indicator lights for function						×	
- Check engine brake control						×	
- Check retarder control						×	
- Lubricate boom receptacle		×					
□ **Emergency control**							
- Check for function					×		
□ **Support plates with compensation**							
- Replace grease filling					×		
- Check for function					×		

8.07 INSPECTION OF PNEUMATIC BRAKE SYSTEM 025045-00



8.07 INSPECTION OF PNEUMATIC BRAKE SYSTEM

025045-00

General
The pneumatic brake system in mobile cranes must be checked annually.
In Germany, this brake inspection must be made according to § 29 STVZO.
For other countries, local and national regulations apply.

1. **Visual inspection**
To check the pneumatic brake system, the following requirements apply:

1.1 Pipe and hose lines are not damaged, not corroded and are properly routed.

1.2 Components are correctly installed and properly mounted.

Note: On membrane cylinders, the lower breather bore (4) must be clear (plug removed). The breather bores (1, 2 and 3) must be closed with plugs.

CAUTION: **The lower breather bore (4) must be clear. If this is not observed, the membrane skin can twist, the accumulator is not fully released, the brake gets hot.**

1.3 Air tank is not damaged, no external corrosion can be seen.
The tank is marked properly.

CAUTION: **No welding nor heat applications may ever be done on the tank walls .**

1.4 Condensation is drained from the air tank.

1.5 Dust guards are not damaged.

1.6 Joints are secured, move easily and have not been knocked out.

1.7 Linkage has not been welded, is not bent, moves easily and is not damaged.

1.8 Brakes are adjusted properly (ventilation, brake cylinder stroke, pad thickness, linkage plate).

2. **Function and action test**

2.1. **Function test**

2.1.1 Pressure regulator, air compressor
Check cut in pressure, cut off pressure and output capacity.

2.1.2 Check seals and reservoir pressure in air pressure system.

2.1.3 Check multi circuit safety valve, overflow valves, warning device.

8.07 INSPECTION OF PNEUMATIC BRAKE SYSTEM 025045-00

2.2 Brake action test

The brake function can be checked through the ports in the cover plates.
If the brake pedal is pressed down, both brake pads must touch the drum, when the brake pedal is released, the brake pads must immediately return to starting position.
The brake action can be checked by measuring delay, brake path or by determining the braking action on a brake test station.

2.2.1 Measure the delay with a declerometer
At a pressure of 6.5 bar, the measured median delay should be $d_m > 4{,}5\ m/s^2$.

2.2.2 Measure the brake path
At a pressure of 6.5 bar, the brake path should be s < as the value given in the chart.

Test speed v [km/h]	Brake path s [m]
20	6.5
30	12.5
40	19.8
50	29.0

2.2.3 Determine braking action on a brake test station
To measure the brake power on the vehicle axles, calculate the braking action as follows:

$$z = \frac{F_1 \times i_1 + F_2 \times i_2 \ldots F_n \times i_n}{G_z} \times 100\ [\%]$$

Gz = Permissible total weight of the vehicle [N]
z = Braking [%]
F1 = Brake power of first axle, which has been measured at p_1 pressure [N]
F2 = Brake power of second axle, which has been measured at p_2 pressure [N]
Fn = Brake power of last axle, which has been measured at p_n pressure [N]

$$i_1 = \frac{p_{N1} - 0{,}4}{p_1 - 0{,}4}$$

$$i_n = \frac{p_{Nn} - 0{,}4}{p_n - 0{,}4}$$

$p_{N1 \ldots n}$ = maximum brake pressure of corresponding axle [bar]
$p_{1 \ldots n}$ = Brake pressure, which is used [bar] at the brake test in the wheel cylinder of the corresponding axle

8.07 INSPECTION OF PNEUMATIC BRAKE SYSTEM 025045-00

3. Internal inspection of wheel brake
Independent of the function and action test, the following tests must be made:

3.1 Every 3 months, the brake pad condition should be checked through the ports in the cover plates.
Every 12 months, pull the brake drum to check the various, internal brake components.

CAUTION: The brake may not be actuated if the brake drum has been pulled.

3.2 Replace the pads when the pad thickness is 5.5 mm (new thickness = 18 mm), measured without taking the thickness of the metal part of the brake pad into account; replace the pads if the pads are burnt, slick or oily.
For replacement, only **Jurid 546**, **Bremskerl 6275** and **Beral 1549** brake pads may be used.

DANGER: Always replace the pads on both wheels of each axle.

3.3 The brake drums should also be turned.

Note: When turning the brake drums, do not exceed the permissible turning measurement of 0.75 % of the nominal diameter!

Example:

Nominal diameter:	500.00 mm
Permissible turning measurement:	3.75 mm
Permissible inside diameter:	503.75 mm

DANGER: If the inside diameter of the brake drum is larger than 503.75 mm, then the brake drum must be replaced.
Otherwise there is a danger of causing a serious accident!

3.4 To correct the brake pad wear or to center the brake, it is equipped with an automatic adjustment device, which is maintenance free.

DANGER: In case of damage to any parts, replace the automatic adjustment device completely, using repair kit "adjustment device".
If this is not done, there is a danger of causing a serious accident!

3.5 The pressure and pull springs as well as seal rings, caps and dust covers must be replaced at least every 2 years.

DANGER: All maintenance and repairs on th brake system must be performed by authorized and especially trained personnel.
Otherwise there is a danger of causing a serious accident!

3.6 After assembly, repeat visual, function and action test.

Kundendienst-Information

Service Information
Information du service

LIEBHERR-WERK EHINGEN GMBH
D-89582 Ehingen/Donau - Tel. (07391) 502-0

Datum	Abteilung	Nr.
11.03.2005	VMS/ju	U090501e

Repair of the wheel brakes with expanding wedge device

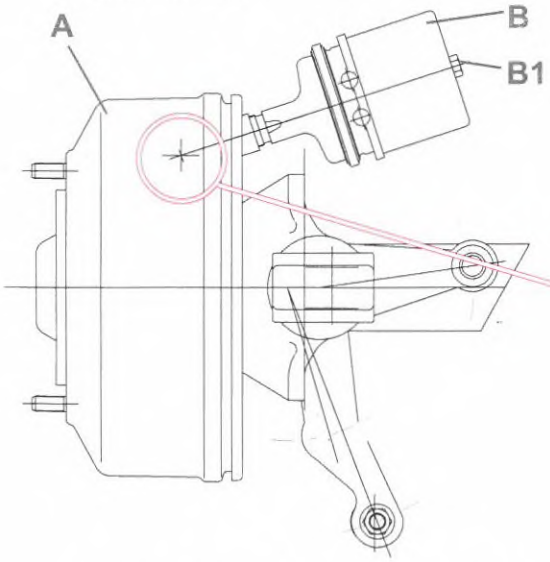
Important indications on the replacement of brake shoes / brake drum

In order to ensure a professional brake repair, absolutely take care of the following:

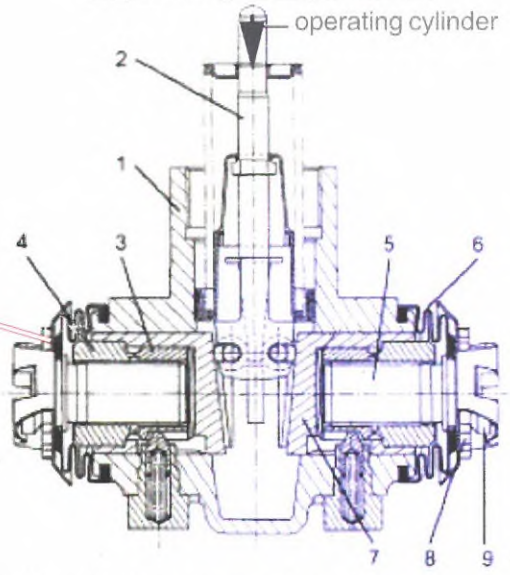
1. **If the brake drum (A) is dismantled, do never operate the brake pedal!**
2. **On wheel brakes with operation by spring brake cylinder (B), unscrew the release screw (B1) before dismantling of the brake drum (A)!**

Reason:
At possible loss of reserve pressure, the expanding wedge (2) is pressed downwards by the reselience in the spring brake cylinder, .
If the expanding wedge (2) is pressed over the edge of piston (7), the expanding wedge (2) is no more reset into its normal position - see below
If the expanding wedge (2) was overpressed (s. below), the expanding wedge device must be repaired or replaced!

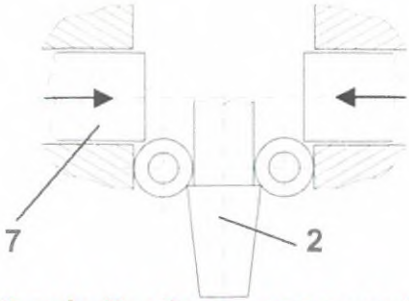
wheel side



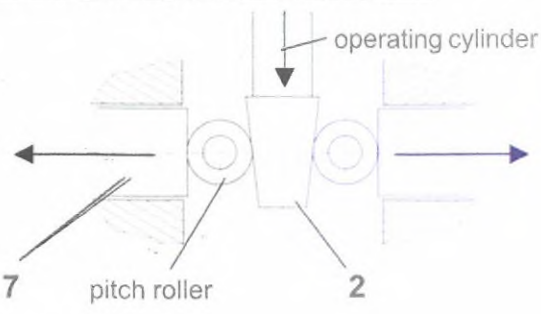
expanding wedge device



expanding wedge - overpressed



expanding wedge - normal position



Further indications - see page 2!

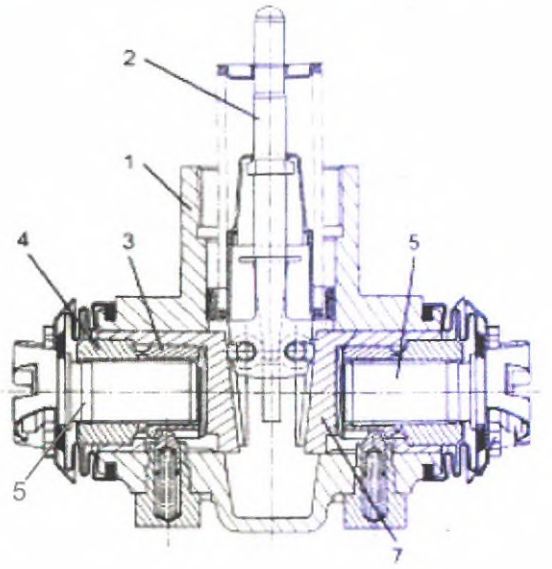
Important indications on the replacement of brake shoes / brake drum U090501e

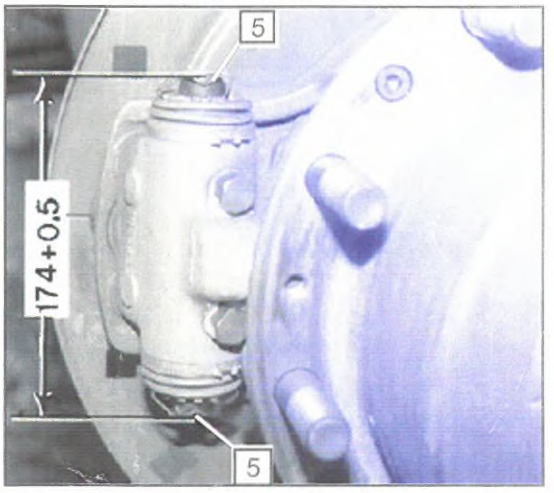
3. During each replacement of the brake shoes, readjust the expanding wedge device!

Basic adjustment procedure:

- Precautiously remove the rubber collar (6) from the groove in the housing (1).
- Pull off readjustment screw (5) incl. readjustment nut (4) and rubber collar (6) from the piston (7).
- Screw readjustement screw (4) against the collar of the readjustment screw (5) to the limit stop.
- **Subsequently, release the readjustment screws (5) by at least 2 turns each!**
  Note:
  Both readjustment screws (5) must be released precisely identically in order to ensure the center position of the brake shoes.
- Press readjustment screws (5) towards the inside and measure the interspace.
  Setpoint value:
  174 mm, tolerance +0,5mm

  Pay attention:
  The setpoint value must be absolute attained, possibly release readjustment screws further!
- After having fitted the brake drum and the wheel, operate the footbrake approx. 15 times to allow the automatic adjustment of the brake's release cycle, specified by design.





Warning:

- **Repair and maintenance of the brake shall only be performed by professional personnel authorized by the manufacturer of the brake or of the carrier!**
- **Employ only original spare parts of the manufacturer of the carrier or of the brake!**
- **The replacement of worn out parts must only be performed per axle!**
- **After termination of work on the brake system, absolutely perform a functional test of the brakes on all wheels!**
  If possible carry out a functional test on the roller type test stand.

Further indications - see workshop manual, Kessler axles (Id. no. 899632308)

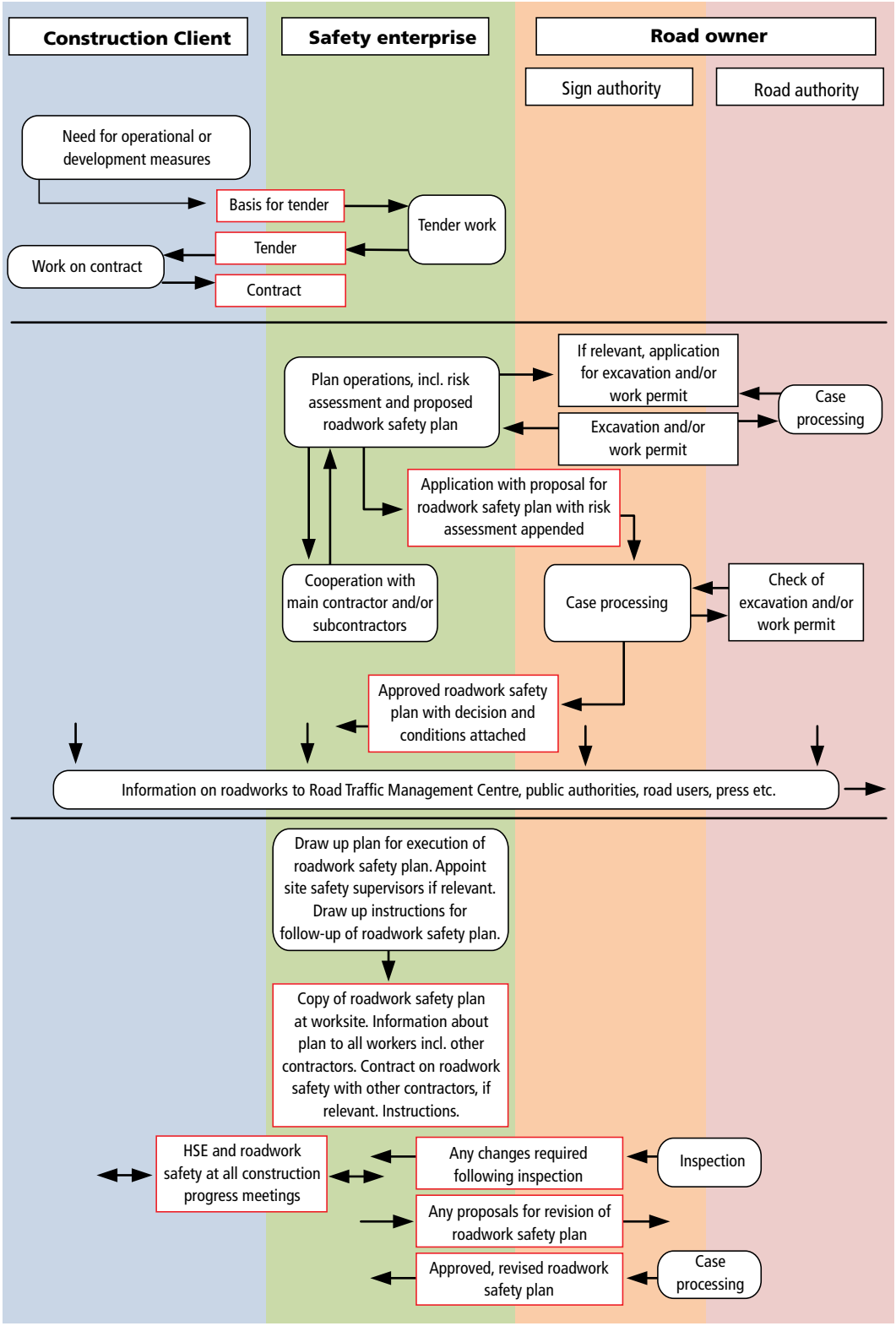


Figure 2.1 Flow chart showing parties involved, responsibilities and important documents

Accident Investigation Board Norway

Recipients according to list

Handled by / phone no.:

Our date:
05.05.2017
Our reference:
17/217-17
Your date:

Your reference:

NOTIFICATION OF CRITICAL SAFETY ISSUE RELATING TO THE INVESTIGATION OF A SERIOUS ACCIDENT INVOLVING A MOBILE CRANE IN KRISTIANSAND ON 7 MARCH 2017

The Accident Investigation Board Norway (AIBN) refers to Regulations No 793 of 30 June 2006 on Public Investigation and Notification of Traffic Accidents etc.:

Section 11. *Information to relevant public bodies.*

> *The investigating authority shall keep relevant public bodies informed about serious findings made in the course of the investigation and, insofar as it is deemed critical in relation to road safety, about its own preliminary assessment of same.*

The basis for this notification is the AIBN's investigation of the serious accident that took place in Kristiansand on 7 March 2017. A mobile crane (2006 model) en route to an assignment on a construction site was temporarily parked on a shared use path. The driver left the driver's cabin to assess the driving conditions. The mobile crane was parked on sloping ground, and it skidded/rolled driverless backwards. It came to rest against a rock face.
A five-year-old boy was hit and died as a result of his injuries. We also refer to further information provided at a meeting about the case held at AIBN's premises on Thursday 27 April 2017.

Examination of the mobile crane has so far determined that the brakes on the middle axle were defective. The preliminary investigation has also uncovered that neither an inspection by an enterprise of competence approximately two months before the accident nor the crane company's own inspections found any problems with the brakes of the mobile crane in question.

We also refer to a previous report concerning an accident involving a mobile crane that took place at Smestad in Oslo in 2007, documented in Rapport om veitrafikkulykke på Smestad i Oslo den 21.juni 2007 hvor en mobilkran kolliderte med en personbil og en motorsykkel | sht (‘Report on a road traffic accident at Smestad in Oslo on 21 June 2007 in which a mobile crane collided with a passenger car and a motorcycle’).

Postal address
Accident Investigation Board Norway
Postboks 213
2001 Lillestrøm
Norway

Office address
Accident Investigation Board Norway
Sophie Radichsvei 17
2003 Lillestrøm
Norway

Phone: + 47 63 89 63 00
Fax: + 47 63 89 63 01

http://www.aibn.no
E-mail: post@aibn.no

Mobile cranes are subject to third-party inspection by certified enterprises of competence for which the Norwegian Labour Inspection Authority has supervisory responsibility. These inspections are to include brake inspections. The Norwegian Public Roads Administration has included cranes registered after 2012 in the periodic roadworthiness test scheme, but the scheme does not cover older cranes.

The AIBN's assessment:
The preliminary investigation of the accident in Kristiansand indicates that maintenance, follow-up and brake inspections of mobile cranes registered before 2012 are still inadequate. It must be pointed out that the condition of the brakes on this crane may have changed after the last inspection, but this has not been documented and will be subject to further investigation.

Based on our findings and assessments relating to these two accidents, the AIBN has chosen to issue a warning about the need for better follow-up of brake inspections of mobile cranes and similar motorised equipment used on roads. This applies in particular to procedures for the annual third-party inspections of mobile cranes registered before 2012.

This issue is so significant and important that the information is communicated before the investigation has been completed in accordance with the regulations. The AIBN therefore submits this notification of a critical safety issue to both the Norwegian Labour Inspection Authority and the Norwegian Public Roads Administration as relevant public bodies in the matter.

The AIBN will continue its investigation of the case, which will also include maintenance and inspection procedures and the reason for and significance of the brake failure.

Regards

William J. Bertheussen
Director General

Rolf Mellum
Director, Road Dep.

This document has been electronically signed.

Recipients:
Norwegian Labour Inspection Authority
Norwegian Public Roads Administration

Copy sent to:
Ministry of Transport and Communications
Nordic Crane Sør AS
Kolos Inspection AS

Postal address
Accident Investigation Board Norway
Postboks 213
2001 Lillestrøm
Norway

Office address
Accident Investigation Board Norway
Sophie Radichsvei 17
2003 Lillestrøm
Norway

Phone: + 47 63 89 63 00
Fax: + 47 63 89 63 01

http://www.aibn.no
E-mail: post@aibn.no

WABCO

SERVICE

Market Information

15 December 2004

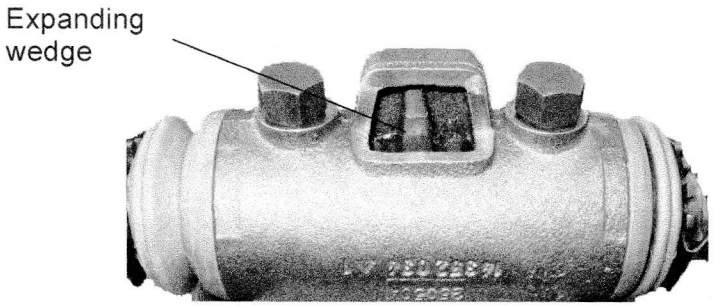
Caution before applying brakes at opened wheel brake!

It should go without saying that there may be grave injuries when you apply the brake pedal while your colleague is working on the brakes. For instance your colleague may have his hand between the closing device and brake drum.

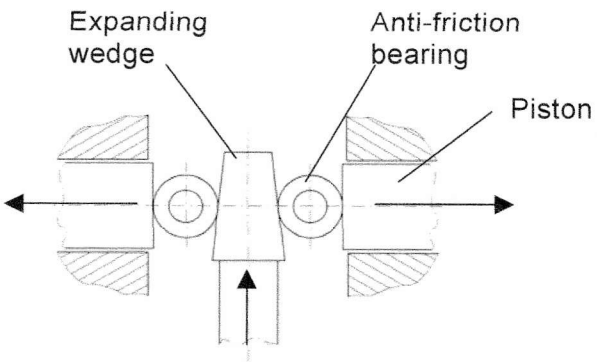
Therefore personnel at workshops should always affix a label onto the steering wheel indicating that repair work is in progress. There may not only be personal injuries, but actuating the brake often "disassembles" it. The actuating elements will slip from their guides with no brake drum or release spring being present and this will lead to the replacement of the actuating elements or an expensive repair.

In the case described here, the affixed label was not noticed. Over the weekend, the expanding wedge device was actuated and without protection from the brake shoes and drum, & due to the pressure loss in the reservoir the spring brake cylinder was engaged. You can clearly see that the expanding wedge in the cross section shown below has come into the "unbraked" position. This will lead to having to disassemble the actuation device as it is the only way to release the part. As represented on the sketch, the anti-friction bearing bodies block the return of wedge.

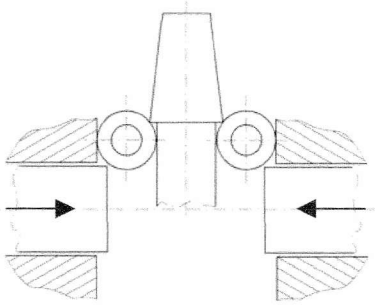
In conclusion: Be cautious when applying the brakes and take note of the pressure in the reservoir! Only in this case will you gain safety by unscrewing the release screw.



Actuating cylinder



Ant-friction bearing and piston block in release direction



Annex F: Excerpts from acts, regulations and guidelines

The Act of 18 June 1965 No 4 relating to road traffic (the Road Traffic Act)

The Road Traffic Act applies to all motor vehicle traffic and other traffic on roads or in areas generally used by motor vehicles. Among other things, the Act regulates the basic rules of traffic, road signs and traffic regulation.

Section 7 Special traffic prohibitions, is the main legal basis for all traffic regulation in connection with roadworks.

The Regulations of 21 June No 747 relating to pedestrian and vehicle traffic (the Traffic Rules)

The following definition is provided in Chapter 1 f) of the Regulations:

Footway and cycle track: 'Any path or track designated by an official traffic sign for the use of pedestrians or cyclists or a combination of pedestrian and bicycle traffic.' Such path or track is separated from other roads by a strip of grass, a ditch, fence, kerbstones or by other means.

Regulations of 7 October 2005 No 1219 relating to public traffic signs, road markings, light signals and instructions (the Road Sign Regulations)

The Road Sign Regulations contain special provisions for roadworks, and Section 32 General provisions reads as follows:

1. *This chapter applies to warning and protection of all works and arrangements on or near public roads. The provisions apply in addition to the other provisions in these regulations.*
2. *The regional roads department is the sign authority for national roads and county roads, and the municipality is the sign authority for municipal roads. The municipality is the sign authority responsible for national roads and county roads for which the municipality has been authorised pursuant to Sections 17 and 18 of the Public Roads Act.*

In addition, Section 33 Responsibilities reads as follows:

1. *The sign authority where the warning is to take place shall approve the sign plan and make the necessary decisions.*
2. *Responsibility for carrying out and follow-up of the plan at the roadworks site shall be given to the agency or contractor performing the work.*
3. *The agency or contractor performing the work shall at each individual work site appoint a person who is responsible for ensuring that the warnings are correct and in accordance with the plan. A copy of decision, logbook, safety plan and any conditions that have to be laid down for the work in question shall exist and be available at the worksite. The person responsible shall ensure that the necessary warning and protection material is present, and that warning and protection at the worksite at all times are in accordance with an approved plan. In the event of illness,*

holidays etc., responsibility shall be transferred to another qualified person. The name and telephone number of the person responsible shall be supplied to the sign authority.

The NPRA's Manual N301 Work on and along roads

Manual N301E *Work on and along roads* describes provisions concerning warning and protection of work on and along roads. Manual N301E is prepared by the Norwegian Public Roads Administration and has norm status. The manual contains specifications concerning traffic signs, signals and road markings, and the legal basis for these specifications is the Road Sign Regulations. The manual also contains important provisions intended to ensure the safety of workers and road users.

The manual targets all those who work on or along roads, particularly those responsible for warnings and protection, and planners of roadwork safety, construction clients, the authorities etc.

The manual has four main chapters; 1. Acts and regulations, 2. Planning and execution, 3. Warning and 4. Protection. Chapter 4 of the manual describes how vulnerable road users are to be protected in connection with work on or along roads:

4.3 Protection against pedestrians and cyclists

It is important that the work areas are protected when pedestrians and cyclists, especially children and the disabled, are affected by roadworks. This applies both when these road users' own traffic area (pavement, footpaths and cycle tracks) are directly affected, and when machines or vehicles move around in or directly next to the pedestrian and bicycle areas.

The manual also describes the procedures for applications, approval and execution of roadwork safety on public roads. In addition, the manual describes how responsibility should be divided between the construction client, the contractor and the road owner, and what a roadwork safety plan should contain.

Regulations of 4 October 1994 No 918 on Technical Requirements for and Approval of Motor vehicles, Parts and Equipment (the Motor Vehicle Regulations)

Mobile cranes registered before 15 September 2012 are classified as motorised equipment covered by the Regulations of 4 October 1994 No 918 on Technical Requirements for and Approval of Motor vehicles, Parts and Equipment (the Motor Vehicle Regulations).

The Regulations of 5 July 2012 No 817 on the approval of road vehicles and road vehicle trailers (The Car Regulations)

Mobile cranes registered after 15 September 2012 are classified as lorries under the Regulations of 5 July 2012 No 817 on the approval of road vehicles and road vehicle trailers (the Car Regulations).

Regulations of 13 May 2009 No 591 relating to periodic roadworthiness tests

Mobile cranes registered after 15 September 2012 are subject to the requirements for annual inspections where NPRA's joint instructions for periodic roadworthiness tests of vehicles[1] is to be followed. There are 26 inspection points listed under the chapter on brake systems. The service brake's performance and effect is described in a separate chapter, 1.2. The inspection method for chapter *1.1.16 Brake actuators* is reproduced:

> *The strokes of the brake can also be checked by measuring the clearance between the brake band and drum.*

Regulations of 25 January 1990 No 92 on the use of vehicles (Vehicle Use Regulations)

These regulations deal with weights and dimensions.

Act of 21 June 1963 No 23 relating to roads (the Road Act)

The Norwegian Road Act defines the road authority. Normally, the Norwegian Public Roads Administration is the road authority for national roads and county roads, while the municipality is the road authority for municipal roads. It is stated in the Road Act Sections 32 and 57 that work must not be carried out on, under, over or by public roads without the relevant road authority's permission.

Act of 17 June 2005 No 62 relating to the working environment, working hours and employment protection etc. (the Working Environment Act)

The Working Environment Act requires that enterprises safeguard employees' health, environment and safety. Regulations of relevance to the AIBN's investigation are listed below. The Working Environment Act and its regulations are administered by the Norwegian Labour Inspection Authority.

Regulations of 20 May 2009 No 544 on machinery (the Machinery Regulations)

The regulations target manufacturers, their representatives, importers, suppliers and other dealers in machinery and products that fall under their scope.

Annex I, section 1.7.4 sets out the requirement that the instructions shall accompany the machinery, and section 1.7.4.2 stipulates more detailed requirements concerning the contents of the instructions, including maintenance instructions.

Regulations of 6 December 2011 No 1360 on administrative arrangements in the area covered by the Working Environment Act (Regulations on Administrative Arrangements)

These regulations concern the exercise of public authority and administrative arrangements relating to safety training, corporate health services, enterprises of competence and regional safety representatives.

[1] https://lovdata.no/static/SF/sf-20090513-0591-01-05.pdf?timestamp=1514768503000

Regulations of 6 December 2011 No 1357 on execution of work, use of work equipment and related technical requirements (Regulations on the Execution of Work)

The purpose of these regulations is to ensure that work is executed and working equipment used in a safe manner, so as to protect the life and health of employees.

Chapters 10, 12 and 13 deal with adequate competence and training in the safe use of working equipment, requirements for systematic maintenance and inspection, and requirements for inspection of the working equipment by a certified enterprise of competence.

Regulations of 3 August 2009 No 1028 relating to safety, health and working environment at building and construction sites (the Construction Client Regulations)

The purpose of the Regulations is to protect employees from risks by paying regard to safety, health and working environment on construction sites in connection with planning, project reparation and execution of building or civil engineering works.

Sections 7 and 8 deal with the plan for safety, health and working environment (HSWE plan) and requirements regarding its content. The client shall ensure that a HSWE plan is prepared for each construction project and that the plan is updated in the event of changes.

Regulations of 6 December 2012 No 1127 relating to systematic health, environment and safety activities in enterprises (Internal Control Regulations)

Internal control shall be documented in the form and to the extent necessary in the light of the nature, activities, risks and size of the enterprise. Documentation resulting from requirements set out in or pursuant to the health, environmental and safety legislation, for example instructions, authorisations, proof of qualifications, certifications and the like, shall be included.