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A ‘normal accident’ with a tower crane? An accident analysis conducted by the Dutch Safety Board

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ABSTRACT

Since cranes and tower cranes are complex installations they constitute critical aspects of safety at construction sites. The risks posed by cranes are specific and should be treated as such. Prior to assessing the impact of management and organizational factors, accident analysis should first start with an analysis of the actual accident process. The Dutch Safety Board conducted such an accident analysis involving a non-mobile, peak less, trolley tower crane. This tower crane collapsed at a Rotterdam building site on July 10th 2008. The results show that the flexibility of the configuration of the mast and the horizontal arm of the crane or the jib was greater than that calculated by the design engineer. While hoisting a heavy load, the crane collapsed. The defects in the design of the crane were not identified, so the accident was classified as a ‘normal accident’, one that was essentially integral to the design and could also thus occur in other tower cranes of the same make. Such tower crane design shortcomings emerge as process disturbances once the crane is operational. Despite its shortcomings, the collapsed crane did have a CE mark. Other officially required safety audits and crane inspections did not address possible defects in the design, production, or operation of the crane. Once on the market there appears to be no further effective safety net for the detection of structural weaknesses. The article will also discuss the role of parties involved in construction and inspection of tower cranes.

1. Introduction

Tower cranes are complex and impressive installations. When cranes collapse due, for instance, to gusts of wind this inevitably hits the regional and/or national news headlines and gets into the trade press (HSL, 2010). Oddly, scientific literature devotes relatively little attention to analysing the causes of crane accidents and considering how they could be prevented (Swuste, 2005; Shapira and Lyachin, 2009). This contrasts sharply with research into the quality of structural elements and the dynamic behaviour of forces during lifting operations (see e.g. Reis et al., 1984; Hambly, 1990; Ju and Choo, 2005; Tong et al., 2007; Hasan et al., 2010).

In Europe, unlike in the United States, tower cranes are widely used in construction projects. The reconstruction period after the Second World War saw a considerable increase in the use of these types of cranes. In the United States mobile cranes have traditionally been the preferred option for lifting loads at construction sites. Only recently has tower crane use begun to increase in the United States (Shapira et al., 2007).

Modern tower cranes are equipped with electronic systems and are software controlled. For instance, they have cameras for ‘blind lifting’, collision warning systems for other cranes and safety devices to prevent load moment exceeding. The load moment (torque) is the combination of the weight of the load and the horizontal distance from the load to the mast – the outreach. If this is likely to be overstepped, the crane driver will get a warning, the system will block all crane movement and it will switch off automatically. The increased technical quality of the cranes is the main reason why scenarios such as ‘crane instability’, ‘jib instability’ and ‘hoisting equipment instability’ contribute little to accidents. Nowadays ‘load instability’ is still the most dominant accident scenario in crane accidents. These accidents, involving falling loads from cranes are as old as the cranes themselves. Safety posters, from the 1920s warned about such dangers (ANC, 2002; Swuste et al., 2010). Fig. 1 shows British and Dutch examples of this. Tower cranes lift their loads over overcrowded building sites. The areas where these cranes operate frequently converge with those of other builders, and lifting is often subject to time pressure. The ‘rigger’ and other construction workers, not involved in lifting activities are often the victims of crane accidents (Beaver et al., 2006; Paas and Swuste, 2006; Tam and Fung, 2011). Tower cranes are therefore a critical component in a series of elements that make construction sites inherently dangerous (Parfitt, 2009; Sertyesilisik et al., 2010).

Crane accident causes are often seen as operator errors on the part of crane operators. Cranes are, however, robust installations

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Fig. 1. Dutch and British posters on crane safety dating from the 1920s (ANC, 2002) Dutch poster text (*van onderen*!: below!, *gevaarlijke plaats*: hazardous location).

and crane drivers are professionals. Lifting activities are risky and management time and finance is always limited. The risks attached to cranes are specific which is why planning must be linked to specific hazards and to crane-centred risks such as those pertaining to its load, its location and its environmental conditions. If these are ignored, the risk will rapidly increase and will create conditions of (in)dependent errors and management decisions thus leading to accidents (Schexnayder, 2003; McDonald et al., 2011).

In recent research an example of a specific form of risk management in the offshore sector was published. Hoisting activities carried out off-shore are generally more risky than those on-shore, due to factors such as weather conditions, limitations in crane manoeuvrability and to the degree of precision required during hoisting activities. On Norwegian platforms in the North Sea, crane operators are supported by several riggers. If riggers notice hesitancy on the part of the crane driver during hoisting or if a crane driver himself notices that it is just 'not his day', then hoisting operations are halted and the crane driver is replaced without the reputation or position of the driver or rigger needing to be affected in any way. The expression 'it's an off day for him today' is an accepted phenomenon in risk communication. There is strong internal control because the consequences of mistakes made during hoisting can have major repercussions (Nævestad, 2008, 2010).

In recent decades, accident investigation has emphasised the impact of management decisions and organizational conditions as distal factors in the accident process. The influence can only be studied if proximal and environmental factors are understood. This not only applies to cranes but also to all accidents that are termed technological (Booth, 1993). Models have already been developed for the proximal and distal factors behind accident processes in crane operations, including a quantification of these factors. The national registry of the Dutch Labour Inspectorate is used as a source (Aneziris et al., 2008). These and other types of registration do, however, have some major disadvantages. Their design is rarely based upon research questions, but rather upon legal obligations, and/or legal inquiries into infringements of the law. This significantly reduces the applicability of registration in accident cause inquiries (Shapira and Lyachin, 2009). So far, it is detailed scenario studies that provide the best guarantee of being able to trace accident causes and their precursors.

On July 10, 2008, a tower crane collapsed in Rotterdam, seemingly without cause. The tower crane was being implemented in the construction of a block of high-rise flats. The crane driver who was situated 96 m above ground level in the crane, died during the accident. The falling crane caused extensive damage to the construction site. Potentially, the accident could have given rise to many more injuries or fatalities on the construction site, on the nearby footpath or in the children's play area. The Dutch Safety Board (Onderzoeksraad voor Veiligheid – OVV), chaired by Professor Pieter van Vollenhoven extensively investigated this accident. The objectives of the investigation are (OVV, 2009):

- To determine the cause of the collapse of the tower crane at Prinsenlaan in Rotterdam.
- To bring light any possible shortcomings in the design of the tower crane.
- To identify a safeguard (or lack thereof) that could identify and help prevent accidents resulting from shortcomings in design or production.
- In addition the question was asked if the crane accident was a so-called 'normal accident'.

This article is largely based on the results of the investigation carried out by the OVV and on the reactions published in relevant professional journals. The OVV investigation was accompanied by an external advisory committee (see Acknowledgement) and a draft version of the report was submitted to parties involved.

2. Method

Immediately after the accident, an OVV research team conducted an on-site survey. It was decided to investigate the accident in two different ways. First there would be a technical investigation into the direct causes of the accident. This study would answer the first two objectives. The second line of inquiry focused on the design of the crane, an analysis of the stakeholders involved and their role in the acceptance of the design. This second aspect answered the third objective.

In the technical study, three different scenarios were extensively studied. The first scenario was the possibility that the accident was due to an exceeding of the operational parameters. The electronic components and the data carrier were checked, as well as what is known as the crane's electronic compatibility. That kind