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Factors that affect safety of tower crane installation/dismantling in construction industry

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ABSTRACT

Construction of high-rise buildings, large-scale apartment blocks, or construction in urban areas (especially busy downtowns) demands increasingly greater use of tower cranes. Therefore, the installation and dismantling of tower cranes on construction sites is an inevitable task, but also one of the most dangerous in the construction industry. Accidents during installation (including assembling and climbing) or dismantling of tower cranes incur the loss of workers' lives as well as delays in construction schedules and/or damage to buildings under construction. The aim of this paper is to investigate factors that contribute to accidents during tower crane installation/dismantling in Korea. Accident analysis and focus group interviews (FGIs) were conducted with people involved in crane work. A total of 38 fatal accident cases involving tower cranes occurred between 2001 and 2011. Accidents occurring during installation/dismantling of tower cranes accounted for 68.4% of all fatal accidents. Accident analysis identified "Not following work procedures" as one of the main causes of these accidents, followed by "unsafe acts of workers." The FGIs investigation revealed the following factors that adversely affected the safety of the tower crane installation/dismantling: competence of the workers; roles of stakeholders such as principal contractors in the tasks; deterioration of tower crane components; and working conditions for conducting the tasks. These results may provide regulators as well as practitioners with insights for improving the safety of tower crane installation/dismantling.

1. Introduction

The construction industry accounts for about 35% of all workers, making occupational safety in complex and dynamic construction work environments a major concern in Korea (Ministry of Employment and Labor, 2013). The occupational accident rate in Korea has decreased in the last 10 years (Kang and Kwon, 2011); however, the growing number of occupational injuries and their deadly consequences has raised questions about the safety record of the construction industry (Rhee et al., 2013). The accident rate per 1000 workers in this industry has grown from 6.55 in 2009 to 8.38 in 2012. The severity rate and the total work loss per annual working has also increased from 2.34 in 2009 to 3.05 in 2012. Cranes rank fourth as objects involved in accidents, behind temporary structures (e.g. scaffolding), construction machines (e.g., backhoes), and construction vehicles. About 2100 crane-related accidents are reported annually and 23.7% of these occur on construction sites. Tower cranes are associated with 7.2% of all lifting equipment accidents in Korea.

Tower cranes are used on construction sites as lifting equipment for their combination of height and lifting capacity. Tower crane incidents, however, are likely to be fatal due to the weights of the objects and the heights to which they are moved (Beavers et al., 2006). U.S. Labor statistics record 632 crane-related construction worker deaths from 611 crane incidents and 17 multiple death incidents resulting in 38 deaths from 1992 to 2006 (Bureau of Labor Statistics, 2008). The most dangerous process that can lead to fatalities at construction sites is the installation/dismantling of tower cranes; for instance, in 2012, the collapse of a tower crane during dismantling at the University of Texas, USA claimed the lives of two workers (OSHA, 2012).

The increasing demands for higher building construction countrywide in Korea, including large-scale apartment blocks or construction in urban areas (especially busy downtowns), has emphasized the importance of safety during tower crane installation and dismantling. However, little attention has been paid to the underlying safety shaping factors for the installation/dismantling of tower cranes. The purpose of the present research was to

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investigate factors that affect the safety of tower crane installation/dismantling in Korea.

2. Literature review

The use of lifting equipment such as cranes, elevators, or hoist lifts is inevitable for lifting materials on construction sites (Shapira et al., 2007). Cranes are a commonly used form of lifting equipment and tower cranes are typically used in construction of projects such as high-rise or large-scale apartment buildings (Hollister, 2011; Park et al., 2013). The "Burk Dubai" in the UAE and the "Freedom Tower" in the USA are two examples of the tallest buildings constructed recently. In Korea, tower cranes have been widely used in constructing large-scale projects or tall buildings, such as apartments in Haeundae, Busan, and Lotte World 2 (currently under construction) in Seoul.

A 'tower crane' is defined as a slewing jib crane with the jib located at the top of the tower, which stays approximately vertical in the working position. This power-driven appliance is equipped with a means for raising and lowering a suspended load and for the movement of this type of loads by changing the radius, slewing, and/or traveling of the complete appliance (BS EN 14439:2006: Cranes: Safety: Tower Cranes). The demand for the construction of tall building or large-scale development projects in Korea has resulted in increased use of tower cranes since 2001 (Choi, 2006). Every tower crane must undergo examination by the inspection authority before use. More than 3000 tower cranes are currently being used in Korea (Table 1). Table 1 shows that 91.9% of all tower cranes used in Korea are T type tower cranes, while only 8.1% are L type tower cranes; this is probably because the T type crane is more flexible than the L type and can be used at any kind of site (Table 2).

In Korea, since 2008, any tower crane with over 3 tons of loading capacity must be registered as a construction facility. A total of 3033 tower cranes are currently registered as construction machinery in Korea (Ministry of Land, Marine and Transportation, 2012). The safety of tower cranes has been one of major concerns of the Ministry of Employment and Labor (MOEL) because the severity of the accidents that occur at construction sites of tall buildings has increased. The national parliament, trade unions, and social groups have also pressed for curbing of accidents related to tower cranes. A series of tower crane related accidents that took place at construction sites in 2004 led to imposition of stricter rules by the Korean Government (MOEL) on the installation, climbing, operation, and dismantling, though revision of the Occupational Safety and Health Standard regulations. The revised safety regulations, in the form of the Occupational Safety and Health Standard (2005), introduced a safety plan for tower cranes whereby employers must prepare written plans for safe installation and dismantling at construction sites and workers must follow these plans. Every plan should contain (i) the type, model, and capacity of the tower cranes; (ii) procedure for installation, assembly, or dismantling; (iii) equipment, safety devices, organizing workers; (iv) the scope of crane operation; (iv) the anchoring method; and (vi) training programs for the workers working with the tower cranes. A Guide for the Tower Crane Erection, Climbing, and Dismantling (revised in 2011) was also published to explain the related procedures in detail.

Table 1
Number of tower cranes with national inspection process completed by year. *Source:* Korea Occupational Safety and Health Agency.

Year	2004	2005	2006	2007	2008
Total	2985	3278	3012	3470	3409
Type					
T type	2767	3033	2749	3197	3133
L type	218	245	264	273	276

A number of studies have been carried out on crane-related safety. These studies fall into one of three categories based on the type of research performed:

1. Statistical analysis or case studies of accidents.
2. Interviews, or surveys of site/work safety; or
3. Modeling of equipment/activities.

An accident analysis by Beavers et al. (2006) found that inadequate performance of crane operators and riggers was the main reason for crane accidents, based on the high probability of accidents indicated by analysis of fatalities occurring during the years 1997–2003 in the USA. Aneziris et al. (2008) used Netherlands accident data to develop a quantifying model for the risk of crane collapse, overturning, or dropping loads/objects. Swuste (2013) studied fatal tower crane accidents in the Netherlands and described accidents involving tower cranes as 'normal accidents' due to their capabilities and the complexity of installation. Examination of tower crane collapses found these to be due to errors by the builders and operators in identification and interpretation of crane capacity and operation (McDonald et al., 2011; Zrnic et al., 2011; Frendo, 2013; Marquez et al., 2014).

Workplace safety is affected by various factors and crane accidents tend to be under-reported in the construction industry; consequently, accident analysis may not reveal all related factors (Shapira and Lyachin, 2009). Shapira and Lyachin (2009) used interview and survey studies to investigate factors that affect safety of tower crane operation at construction sites and identified 21 factors, categorized into four groups: project conditions, environment, human factors, and safety management. However, their study excluded the installation/dismantling of tower cranes. Sertyesilisik et al. (2010) investigated lifting operations from the planning stage to operation in the UK and found that the experience and knowledge of crane teams needed improvement and that training issues regarding inspection and maintenance required careful monitoring. Tam and Fung (2011) pointed out the importance of underlying conditions for tower cranes in a Hong Kong case study. Kim (2013) surveyed the working conditions of tower crane operators and found that workers encountered more difficulties related to the climate and physiological and psychological elements when working on high-rise buildings than when doing general building jobs.

A model development study by Li et al. (2012) proposed a virtual safety training system for tower crane dismantlement work. Shapira et al. (2012) developed an integrative model for quantitative evaluation for safety on construction sites with tower cranes. Other research has focused on enhancing the performance of cranes and their operation (Rosenfeld and Shapira, 1998; Kim and Singhose, 2010; Kim et al., 2011; Chi et al., 2012).

Research indicates that the prevalent causes of crane-related accidents include human error such as carelessness because construction safety largely depends on worker performance (Shapiro et al., 2000; Beavers et al., 2006). Inadequate safety training and unsafe working conditions are other factors (Sertyesilisik et al., 2010; Tam and Fung, 2011).

The literature on tower crane safety at construction sites, however, has mainly focused on the operation of cranes rather than on their installation/dismantling (Shepherd et al., 2000; Aneziris et al., 2008; Rezazadeh et al., 2011). The present paper contributes to the investigation of tower crane installation/dismantling at construction sites by exploring factors that affect work safety through an examination of accident cases and by conducting a focus group interview to identify influencing factors that should be taken into consideration. In this way, the research distinguishes itself from earlier studies.