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Fatalities of repair, maintenance, minor alteration, and addition works in Hong Kong

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Abstract

This study examines fatalities of repair, maintenance, minor alteration, and addition (RMAA) works which occurred in Hong Kong between January 2000 and October 2011. A total of 119 RMAA fatalities were recorded. Particular emphasis was placed on fall from height accidents as they accounted for the vast majority of RMAA fatal accidents for the period. A cluster analysis was conducted on fall from height fatal cases. The cluster analysis clearly identified three groups of fall from height fatalities: 1) bamboo scaffolders aged between 25 and 34 who fell from external wall/facade in the beginning of weekdays; 2) miscellaneous workers aged between 45 and 54 who fell from other/unknown places in the end of weekdays; and 3) manual labour aged between 35 and 44 who fell at floor level/from floor openings in weekends. Unsafe process and improper procedures were the main unsafe condition leading to fatalities whereas safety belt not properly used was the main unsafe action leading to fatalities. Specific safety interventions were recommended for each of these groups to help avoid these fatalities.

Keywords: Fatalities, repair, maintenance, two-step cluster analysis

1. Introduction

Fatal accident case analysis is important in safety research because it can reveal the root causes of accidents, providing valuable information for designing future preventive measures. Fatal construction accident analysis has been conducted on different types of accidents and different types of works, such as: electrocution (Janicak, 2008; Chi et al., 2009), fall of person (Huang and Hinze, 2003; Chi et al., 2005), struct-by (Hinze et al., 2005), crane operation fatalities (Beavers et al., 2006); heavy equipment and truck-related fatalities (McCann, 2006), and trenching related fatalities (Arboleda and Abraham, 2004). However, fatal accident analysis on repair, maintenance, minor alteration, and addition (RMAA) works remains limited. This may be due to the lack of accident statistics of RMAA works in most of the government departments regulating safety and health issues.

The RMAA sector has been increasingly important to the construction industry. As shown in Table 1, the RMAA sector expanded from 23.5% of the total construction volume in 1998 to 45% in 2010. The importance of RMAA works to the construction industry of Hong Kong is expected to increase further. The number of buildings in Hong Kong aged 50 years or older is approximately 4,000 at the time of writing the paper and will increase by 500 every year. Similarly, the number of buildings aged 30 years or older is 17,000 and will increase to

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28,000 in 10 years (Buildings Department, 2010). In view of the long-standing problem of building neglect, the Hong Kong government has launched a couple of schemes, namely, Mandatory Building Inspection Scheme (MBIS) and Mandatory Window Inspection Scheme (MWIS) to ensure proper maintenance of the ageing building stock.

Under the MBIS scheme, 2,000 private buildings aged 30 years or above, except domestic buildings not exceeding three storeys, will be subject to building inspection each year. The selected buildings will be required to undergo an inspection, followed by appropriate repair and maintenance work. Thereafter, inspections are to be performed every 10 years (Development Bureau, 2010). The MWIS will cover private buildings aged 10 years or above, except domestic buildings not exceeding three storeys. Approximately 5,800 private buildings will be selected every year, requiring their owners to carry out inspection and repair works. After the first inspection, window inspections will be required once every five years (Development Bureau, 2010). With the implementation of the Minor Works Control System on 31 December 2010 (Buildings Department, 2011), the approval procedures of minor RMAA works have been simplified. To dovetail the implementation of these new policies, the Hong Kong government has set up various subsidy schemes and has provided technical assistance to encourage the maintenance of old buildings.

As the RMAA sector expands, safety of the RMAA sector deserves greater attention. Referring to Table 2, the percentage of RMAA accidents to all construction accidents has increased nearly threefold from 17.9% in 1998 to 51.3% in 2008. In 2010, the RMAA sector accounted for 49.3% of accidents in the construction industry (Table 2), whereas it contributed to only 45.0% of the construction volume (Table 1). Even more shockingly, six out of nine fatalities in the construction industry in 2010 were from RMAA works (Table 2), accounting for 66.7% of the overall fatality rate in the construction industry. With the surging RMAA sector, the spate of RMAA accidents is expected to increase. Thus, the safety issue of RMAA works urgently needs to be addressed. In view of the rising importance and worsening safety performance of RMAA works in Hong Kong, the Labour Department started to keep a separate record of RMAA accident statistics and case analysis (Labour Department, 2008) in 2008. In order to curb fatal accidents of RMAA works, the circumstances of past RMAA fatalities and characteristics of the victims involved should be properly analyzed.

Chan et al. (2008) examined 22 fatal cases of the fall of person from height of RMAA works in Hong Kong from 2000 to 2004. The current study extends the analysis further by including the RMAA fatalities to October 2011 to unveil the accident patterns and identify a typology of the major type of fatalities of RMAA works. Significance of the study lies on identifying a typology of RMAA fatalities and providing a basis for in-depth analysis and resulting into finer-grained safety interventions.

(Insert Table 1 & Table 2 here)

2. Characteristics of RMAA works in Hong Kong

The RMAA sector accounted for an average of 50.2% of the construction volume in Hong Kong from 2006 to 2010 (Census and Statistics Department, 2007, 2008, 2009, 2010, 2011). Due to the rising awareness of building sustainability and burgeoning problems of ageing building, the volume of RMAA works continues to rise. As the RMAA sector expands, the safety problems of RMAA works also accelerate. Very often, RMAA projects are small in size and are undertaken by small/medium-sized RMAA contracting companies (Hon et al., 2010, 2011). They are likely to have less resource for safety and lower safety awareness.

Short duration and scattered location of RMAA works make safety supervision difficult. Risks involved are easily to be undermined because many RMAA works involve seemingly minute tasks and are conducted in occupied buildings (Hon et al., 2010, 2011). However, risks of RMAA works are not necessarily lower than new construction works. The chances of having fall incidents may be even higher because many types of RMAA works involve working at height at the external wall/facade, such as erecting truss-out bamboo scaffolding, painting of external wall, installing/repairing air-conditioning, and changing water pipes. Bamboo truss-out scaffold is a unique feature of Hong Kong. It is commonly used for the repair of external drain pipes, spalling concrete, loose external rendering, removing external unauthorized building works, etc (Buildings Department, 2006).

Illustrations of truss-out bamboo scaffold are shown in Fig. 1 and Fig. 2. According to guidelines on the design and construction of bamboo scaffolds of the Buildings Department (2006), the rakers, standards and parallel ledgers must be supported by steel brackets fixed to the structural elements of a building. The overall height of a truss-out bamboo scaffold should not exceed 6 m. The truss-out bamboo scaffold should be designed by a competent person or an engineer. Before erecting the truss-out bamboo scaffold, the external wall has to be properly examined to check whether it is structurally sound to support the truss-out bamboo scaffold. Loads applied to the truss-out bamboo scaffold should be strictly controlled. The holes drilled for the anchor bolts should just fit the anchor bolts. The anchor bolts should be drilled into the wall and not just the surface finishings of the wall. The steel brackets should not be positioned too close to the wall edges. Each steel bracket should be installed with three anchor bolts unless otherwise approved by a competent person. The truss-out bamboo scaffold should have an appropriate working platform protected by covering. It should be constructed by an experienced worker and supervised by a competent person. During erection of the truss-out bamboo scaffold, workers must wear a safety belt which is attached to an individual lifeline or an anchor point that can resist a tensile force of 5 kN. The safety belt must not be attached to the window, window frame or any other object which would be unstable. The truss-out bamboo scaffold should be maintained by a competent person and dismantled once the work has been completed.

Although it is a convenient way for providing a working platform of repair and maintenance works at the external wall, some problems may occur in the installation procedures (Chan et al., 2006). More attention should be given to erection and dismantling of truss-out bamboo scaffolding.

(Insert Fig. 1 & Fig. 2 here)

3. Fatalities in construction

According to the Occupational Safety and Health Administration (OSHA) (2011), one-fifth of the worker fatalities occurred in the United States (US) came from the construction industry in 2010. Fall from height (n = 260, 35%), electrical shock (n = 76, 10%), struck-by (n = 63, 8%) and caught in/ between (n = 32, 4%) were the “Fatal Four” in 2010. These “Fatal Four” were responsible for nearly three out of five (57%) construction worker deaths in 2010 (OSHA, 2011).

Falls from height is the most frequent type of accident resulting in fatalities in most construction industries. Thus, fall from height accident has drawn particular attention (e.g. Huang and Hinze, 2003; Chi et al., 2005; Chan et al., 2008). Huang and Hinze (2003) examined the accident data of the US construction industry from January 1990 to October 2001. Huang and Hinze (2003) found that most fall accidents took place at elevations of less than 9.15 m (30 ft) occurring mainly on new construction projects of commercial buildings and residential projects of low construction cost. The worker’s experience did not seem to diminish accident occurrence. Fall from roof was the top place for fall accidents to occur and roofing was the most frequent task performed when fall accidents occurred. Misjudgment of hazardous situation was the major human error contributing to falls.

Chi et al. (2005) examined the fatal fall accidents occurred in the construction industry of Taiwan between 1994 and 1997. Their study shows that the majority of victims were aged between 25 and 44 years old. Approximately 80% of victims had less than one year of working experience. Fall accidents mainly occurred in scaffolds or existing floor openings. Lack of complying scaffold was the major cause of fall accidents.

Chan et al. (2008) analyzed 22 number of fall from height fatalities in the RMAA sector of Hong Kong from 2000 to 2004. The results show that fall from height accidents mostly occur in Friday afternoons. Workers aged between 45 and 49 had the greatest number of fall accidents. Workers with six to ten years of working experience were more susceptible to fatal accidents. Falls mainly occurred at two levels of height, greater than 16 m and less than 5 m. Labour, scaffolders, and electricians were the trades that experienced the highest number of fatal fall accidents. Bamboo scaffold was the most frequent place of fall.

According to Cheng et al. (2010), small construction companies are likely to have higher injury risk than large construction ones in most countries. The owners of small construction companies may deal with safety differently from large construction companies because of their small scale and lack of resources. Accident cases of RMAA works which are undertaken by many small/medium-sized companies should be analyzed as they may reveal accident patterns quite different from new construction works.

4. Research methods

4.1 Source of data

A total of 90 fatal cases of RMAA works for the period between 2000 and 2007 were provided by the Labour Department of the Hong Kong government. Due to the confidentiality of the fatal case reports, the data released were coded into a pre-determined classification system in EXCEL format by the Labour Department. Since fatal cases of RMAA works occurred after 2007 were not available in the public domain, a systematic search for fatal cases of RMAA works occurred after 2007 was conducted through the electronic database called "Wisenews", which provides access to contents of major local newspapers in Hong Kong. The search resulted in another 29 fatal cases for the period between 2008 up to 31 Oct 2011. Details of these cases were cross-referenced and verified by at least two reports of different newspapers before entering the corresponding details to the EXCEL template provided by the Labour Department.

4.2 Coding variables and classification categories

Variables and classification categories of the EXCEL template were designed with reference to Huang and Hinze (2003) and Chan et al. (2008), and also comments from the Labour Department. Key coding variables include: 1) Time of accident; 2) Day of week of accident; 3) Month of accident; 4) Year of accident; 5) Type of accident; 6) Gender of victim; 7) Age of victim; 8) Trade of worker; 9) Length of experience; 10) Body part injured; 11) Injury nature; 12) Place of accident; 13) Agent involved; 14) Type of work being performed; 15) Safety education and training; 16) Use of safety equipment; 17) Employment condition; 18) Unsafe condition; and 19) Unsafe action.

4.3 Data analysis

A total of 119 fatal cases coded in the EXCEL template were inputted into and analyzed with SPSS 18. Descriptive statistics were utilized to analyze the overall pattern of the fatality records. A preliminary scanning of the data shows that fall from height was the most important cause for death. Due to limited length of the paper, only fall from height fatal case analysis was reported in this paper. To identify a typology of the fall from height fatal cases, cluster analysis which classify objects into meaningful groups on a set of selected characteristics was utilized (Hair et al., 2010). A two-step cluster analysis was employed in this study because it can handle both continuous and categorical variables, determining the optimal number of cluster automatically (SPSS, 2001; Garson, 2010). The two-step cluster analysis firstly pre-clusters the data using a sequential clustering approach. It examines each case and decides if the current record should merge with the previously formed cluster or start a new cluster based on the distance criterion. Freley and Raftery (1998) proposed utilizing Bayesian information criterion (BIC) as the criterion statistic. The second step takes sub-clusters from the first step as input and then groups them into a number of clusters (Garson, 2010). The literature shows that age, trade, place of accident, and day of accident are distinguishing features of fatalities in construction (Huang and Hinze, 2003; Chi et al., 2005; Chan et al., 2008). Thus, these features were selected to form the clusters. Cross tabulation analyses were then conducted to further explore characteristics of the clusters.

5. Results and discussions

5.1 Descriptive statistics

As shown in Table 3, the fall of person from height (*n* = 74, 62%) and contact with electricity (*n* = 20, 17%) were the two major causes for RMAA fatalities between 2000 and 2011. To gain a better understanding of the major causes for RMAA fatalities, this paper focuses on analyzing the 74 cases of fall of person from height.

(Insert Table 3 here)

5.2 Cluster analysis

A cluster analysis was then conducted on 74 fall from height fatal cases. Outlier treatment of noise handling at 25% was selected. After the cluster features (CF) tree was formed, the outliers would be placed in the CF tree if possible, if not, the outliers would be discarded accordingly (SPSS, 2001). Three fall of person from height fatal cases were classified as outliers, the remaining 71 cases were formed into three clusters (Fig. 3). Average silhouette is 0.3 indicating that the cluster quality is fair (Below 0.2 is poor, 0.2-0.5 is fair, 0.5-1.0 is good). As shown in Fig. 4, Cluster 1 was labeled as bamboo scaffolders aged between 25 and 34 who fell from external wall/facade in the beginning of weekdays (*n* = 31); Cluster 2 was labeled as miscellaneous workers aged between 45 and 54 who fell from other/unknown places in the end of weekdays (*n* = 27); and Cluster 3 was labeled as manual labour aged between 35 and 44 who fell at floor level/ from floor openings in weekends (*n* =13).

(Insert Fig. 3 here)

Cluster 1 Bamboo scaffolders aged between 25-34 working at external wall/facade in the beginning of weekdays

This cluster consists of the vast majority of the relatively young bamboo scaffolders. Many accidents happened in the afternoon in the beginning of the week in the summer, that is, Monday and Tuesday afternoons in the summer. Accidents occurred when the bamboo scaffolders were working on the bamboo scaffolding, either erecting or dismantling bamboo scaffolding/ truss-out scaffolding. Most of them were employees.

Cluster 2 Miscellaneous trades of RMAA workers aged between 45-54 working at other/unknown places in the end of weekdays

This cluster mainly consists of miscellaneous trades of RMAA workers including plasterer, plumber, jointer, and others. Accidents occurred in lift shaft/internal work surface, excavation/underground/basement, and others. This cluster of fatalities mostly occurred in the summer afternoon on Thursdays and Fridays.

Cluster 3 Manual labour aged between 35-44 working at floor/floor opening in weekends

Workers in their early middle age undertaking demolition work and others type of works fall at floor level or fall into floor openings. Accidents mostly happened in the afternoon on Saturdays and Sundays in the summer.

(Insert Fig. 4 here)

Table 4 shows the cross-tabulation results of the 71 fall from height fatalities and the three clusters. About 49% of 71 fall from height fatalities (*n* = 35) occurred in the afternoon. Twenty three (*n* = 23) fatalities occurred in the beginning of weekdays and in the end of weekdays respectively whereas far less fatalities occurred in the middle of weekdays (*n* = 13) and weekends (*n* = 12). Younger workers (aged between 25 and 34) tend to have accidents in the beginning of weekdays (*n* = 13) whereas the older workers (aged between 45 and 54) tend to have more accidents in the end of weekdays (*n* = 11). These may be explained by the fact that younger workers tend to have more entertainments during weekends and hence may not get back to working mode when they resume work in the beginning of weekdays whereas older workers tend to get fatigue towards the end of weekdays because of the cumulative effect. The number of fatalities occurred in summer (*n* = 30) far outweighed other seasons, accounting for about 42% of the 71 fall from height fatalities. Overall speaking, workers aged between 45 and 54 (*n* = 20) were more prone to accidents. Victims aged 45 or above (*n* = 35) accounted for about 49% of the 71 fall from height fatalities. It seems that age is a contributing factor for RMAA fall from height fatalities. Most of the victims were injured in multiple locations (*n* = 44) and had multiple injuries (*n* = 46). About 59% of fall from height fatalities occurred in external wall/facade (*n* = 42). Floor/floor opening was the next common place of fall from height fatalities (*n* = 14). Apart from the category of others, scaffolding/gondola was the most frequently involved agent (*n* = 31). Bamboo scaffolding was the most accident-prone type of work (*n* = 24). Shockingly, about 63% of victims were not provided with any safety equipment (*n* = 45). Most of the fatalities were employees (*n* = 50).

(Insert Table 4 here)

In terms of trade, bamboo scaffolders accounted for the greatest number of fatal falls (*n* = 24). Hence, a separate fatality analysis of bamboo scaffolders was conducted and results are shown in Table 5. Regarding the bamboo scaffolding trade, young bamboo scaffolders were more prone to accident than their older counterparts. The number of fatalities of bamboo scaffolders in RMAA works aged below 34 was 14, accounting for 58% of total number of fatalities of bamboo scaffolders in RMAA works. However, comparing with the age profile of registered bamboo scaffolders in Hong Kong, the number of bamboo scaffolders aged below 34 was a mere 22% (Construction Workers Registration Authority, 2011). This implies that 22% of the workforce (those aged below 34) accounted for 58% of the total fatalities. The current findings indicate that younger bamboo scaffolders with less experience were more prone to fatal accidents than their older counterparts.

(Insert Table 5 here)

Improper procedure (*n* = 51, 72%) and unsafe process or job method (*n* = 48, 68%) were the top two unsafe conditions (Fig. 5) whereas failure to use safety belt/harness was the top unsafe action (*n* = 50, 70%) (Fig. 6) found in the fall from height RMAA fatalities. Cluster one accounted for most of the improper procedure, unsafe process, and failure to use safety belt/harness, implying that younger bamboo scaffolders tended to pay less attention to the safety practices than the more experienced ones. More safety training and supervision should be given to the younger bamboo scaffolders.

(Insert Fig. 5 & Fig. 6 here)

6. Discussions and recommendations

Findings of the current study are in line with Chan et al. (2008) but provide finer analyses. The current study finds that fall from height accidents mostly occurred in the end of weekday afternoons, that is, Thursday and Friday afternoons. Afternoon in the summer is the most accident prone period of fall from height fatalities (n = 35). Hot and humid weather may affect workers' judgment and lapse of attention (Chan et al., 2012).Workers aged between 45 and 54 had the greatest number of fall accidents. This is naturally the case because 55% (i.e. 153,392 out of 277,305) of the total workforce in the construction industry aged 45 and above (Construction Workers Registration Authority, 2011), reflecting that the construction workforce in Hong Kong is ageing rapidly and the industry also experienced difficulties in recruiting youngsters.

In terms of trade, bamboo scaffolders were particularly susceptible to fatal falls. Statistics of registered bamboo scaffolders in Hong Kong as at 14 October 2011 (Construction Workers Registration Authority, 2011) show that those aged below 34 only represented 22% of the total workforce. However, findings of the current study indicate that 58% of RMAA fatalities of bamboo scaffolders occurred in this age group. Younger bamboo scaffolders are more susceptible to fatalities in RMAA works. Being less experienced, they may not be able to identify the risks involved in erecting or dismantling bamboo truss-out scaffold for RMAA works competently. Similarly, the study of Chi et al. (2005) in Taiwan shows that young workers were more susceptible to accidents; and workers with less than one year of experience accounted for about 80% of the fatal falls. The analysis result on fatalities of bamboo scaffolders is particularly noticeable. Such an alarmingly high fatality rate of young bamboo scaffolders in RMAA works may further deter new entrants from joining the bamboo scaffolding trade. If the situation persists, this trade may become obsolete.

It is annoying to find out that 63% (n = 45) of the victims were not provided with safety equipment. Workers were forced to take risk when working at height in these fatality accidents. This is absolutely not tolerable because owners of RMAA contracting companies are legally responsible to provide a safe working environment and necessary safety equipment for their employees. Although small/medium-sized RMAA contracting companies may not have adequate resources for safety, they should not neglect the importance of providing sufficient personal protective equipment to workers. Failure to use safety belt/harness was the most frequent unsafe action. Workers should have objected to risk their life to work at height without any safety protections and refused to work in unsafe condition. This indicates that safety education and compliance of safety practices in the RMAA sector are far from satisfactory. To a certain extent, seemingly safe environment and small/minute task characteristics of RMAA works may have discouraged RMAA workers to use safety belt/harness.

It is noted that nine fatalities occurred even when the deceased wore safety harness. These cases indicate that the workers may not have used the safety harness properly or they may not have chosen the appropriate type of safety harness. According to the guidance notes issued by the Labour Department (2005), safety harnesses available in the market may not have met the European or the American standard. At present, only full body harness is acceptable in the US. OSHA revised the regulations involving fall prevention in 1996. The 1996 revision of regulation stipulates that it is not acceptable to use body belt as a personal fall arrest system (PFAS). Body harness is mandated to provide proper protection to workers (Huang and Hinze, 2003). However, it is not uncommon to see a RMAA worker in Hong Kong using a sub-standard safety belt/semi-safety harness, or even worse a self-made safety belt (Apple Daily, 31 July 2008). Sometimes, a fall accident sadly occurs because the safety belt is loosened and not manufactured to the stipulated standard. Had the victim used a full body harness, the fall accident might have been avoided. Most of the fatal accidents happen because the lanyard of the safety harness is not attached to an independent lifeline or a fixed anchorage point (Huang and Hinze, 2003; OSHC, 2004). Some just attach the lanyard to the bamboo scaffold or the truss-out brackets. These are not reliable anchorage points and often fail to provide rescue to the fall victims. Some bamboo scaffold accidents occur because of unlocking the hook when changing position (Huang and Hinze, 2003).

The first cluster identified was bamboo scaffolders aged between 25 and 34 working at external wall/facade at the beginning of weekdays. Bamboo scaffolders are the most accident-prone workers. This is not surprising because they need to work at height at external wall most of the time. As for RMAA works, truss-out bamboo scaffold has caused many deaths. Truss-out bamboo scaffold should be fixed with three anchor bolts. However, in some circumstances, the truss-out bamboo scaffold supported by three anchorage bolts still collapses because the external facade of the old building is not structurally sound (Apple Daily, 4 July 2008). Weather also contributes to the occurrence of accidents. In rainy days, the truss-out bamboo scaffold fixed to the brick wall is dangerous because the tensile strengths of the anchor bolts are greatly reduced when the bricks expand after absorbing water (Tai Kung Pao, 4 July 2008). There are no fast and fixed rules for erecting a truss-out bamboo scaffold. Precautions have to be taken in response to the specific circumstances.

The second cluster identified was miscellaneous trades of RMAA workers aged between 45 and 54 working at other/unknown places in the end of weekdays. This group of fatalities includes a number of trades, such as plasterer, plumber, jointer, and others. Accidents occurred in lift shaft/internal work surface, excavation/underground/basement, and others. RMAA works are usually multi-tasking, types of works are very diversified. The present categorization system cannot fully reflect all of the work trades. Hence, fatalities of this cluster are relatively unclear which warrant further investigations. However, this cluster suggests that ageing workers are more prone to accidents because of reduced strength and flexibility.

The third cluster identified was manual labour aged between 35 and 44 working at floor/floor opening in weekends. Another major type of fall from height fatalities occurred at floor/floor openings. This is easily overlooked but records show that fall from height from the ladder or working platform has led to a number of deaths (Chi et al., 2005; Chan et al., 2008). The most common causes of this cluster are often the overturning of ladders or inappropriate working platforms and unguarded floor openings (OSHC, 2004). Project works undertaken on weekends are not noticeable and are subject to less surveillance but they could cause serious fatalities. For example, a tragedy involving 6 fatalities occurred on a Sunday in the

International Commerce Centre, which is one of the latest landmark constructions in Hong Kong. Six workers fell into the lift shaft when the working platform was overloaded with construction debris (Hong Kong Headline, 14 September, 2009).

After analyzing the characteristics of the first cluster, it is recommended that young bamboo scaffolders should receive more and proper training for erecting bamboo truss-out scaffolds with respect to different circumstances of RMAA works. Truss-out bamboo scaffolds are so unique in Hong Kong and so common in RMAA works that specific training should be given and proper procedures should be laid down. Innovative devises and substitute of bamboo truss-out scaffolds such as Rapid Demountable Platform (Cheung and Chan, 2011) should be encouraged to minimize the usage of accident prone truss-out bamboo scaffolds. Proper usage of safety harness should be promoted. The government should review the standards of safety belts for working at height and encourage the mandatory use of full body harness. Because only limited information was available for the second cluster, only a general recommendation can be provided to those in the late middle aged RMAA workers. They should pay attention to the problem of fatigue especially towards the end of weekdays. For the third cluster, usage of appropriate working platform should be promoted and notices and guarding should be put on floor openings. Although there is difficulty in surveillance on weekends, the supervisor or contactor should keep a close eye on work safety. Unskilled labour doing manual work or demolition should not neglect the risk of the seemingly minute tasks.

7. Conclusions, limitations, and further studies

This paper has analyzed 119 fatal cases of RMAA works in Hong Kong with particular focus on fall from height fatalities which accounted for the vast majority of accidents. Three clusters of fall from height fatalities were identified. Cluster one was the bamboo scaffolders aged between 25-34 working at the external wall in the beginning of weekdays. Cluster two was the miscellaneous workers aged between 45-54 working at other places in the end of weekdays. Cluster three was the labour aged between 35-44 working at the floor openings on weekends. These findings have identified the most typical groups of the fall from height fatalities and thus help the industry or the government to tailor effective safety interventions for RMAA works. Recommendations are given accordingly. This study is limited by data availability because data after 2007 are currently unavailable in the public domain. This study attempts to use newspaper archives to capture fatalities after 2007. Admittedly, this method may not have provided a full picture of all the reported cases. However, reliability of the data from the newspaper archives were cross-referenced and verified by at least two reports of different newspapers. Having analysed the top-one killer in this paper, our next challenge is to conduct similar investigations to the top-two killer, i.e., electrocution in RMAA works, and perhaps to other industries as well. Future research endeavours should be extended to cover other types of fatal accidents, other types of work, other industries, and other geographical locations so that our ultimate goal towards achieving “zero accident” may be realised.

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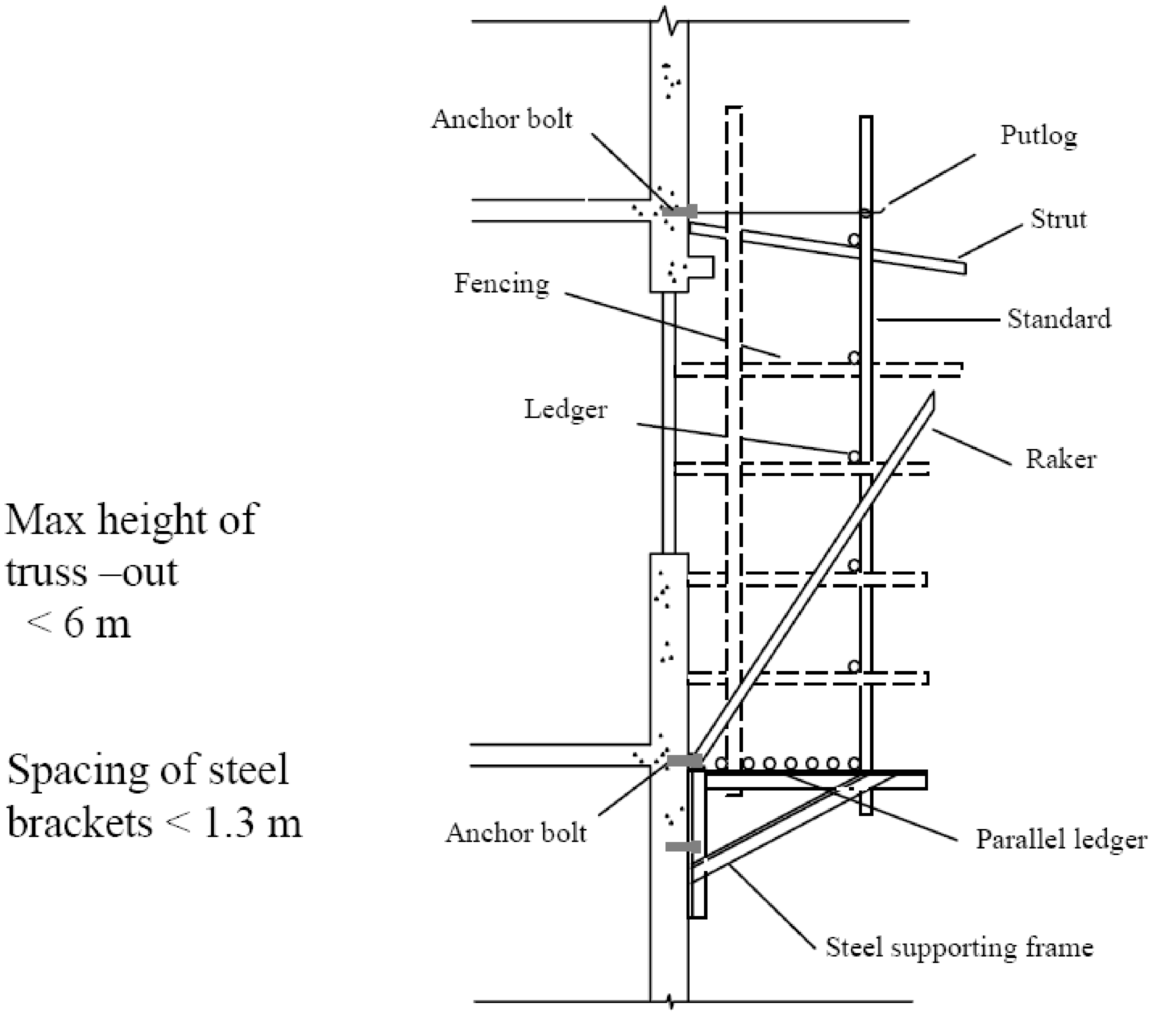

Fig. 1. Truss-out bamboo scaffold (Adopted from Buildings Department, 2006).

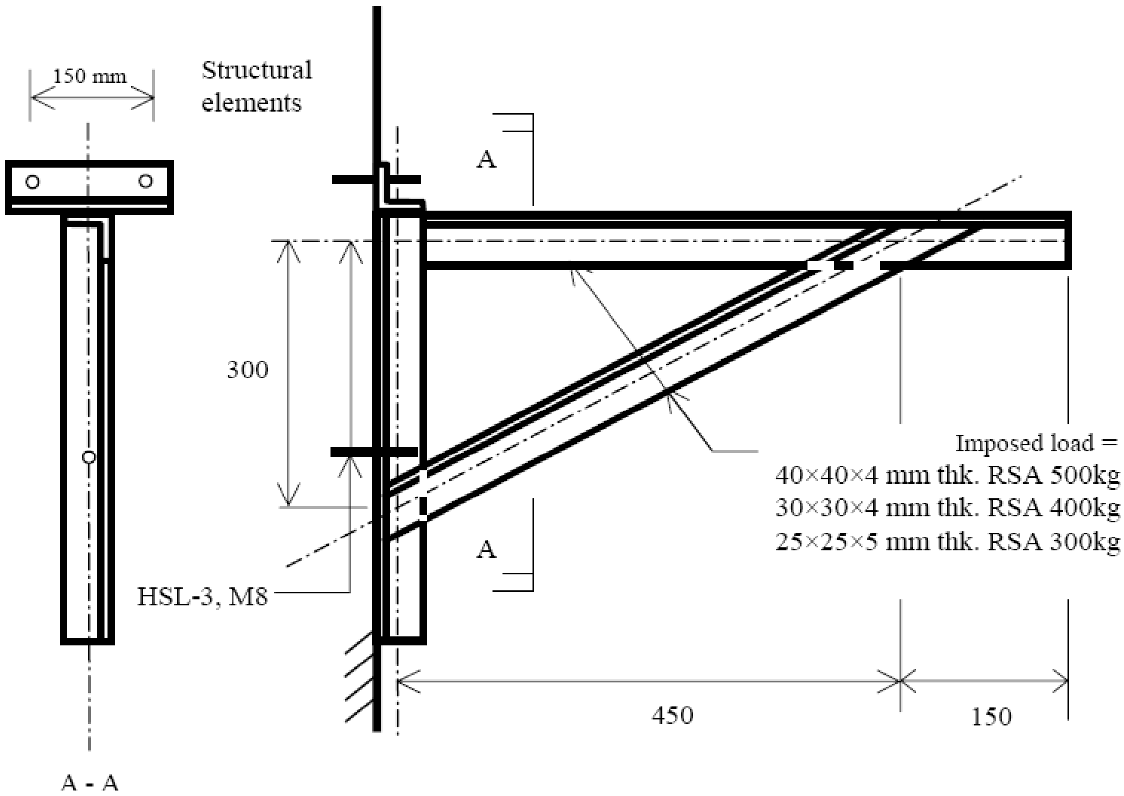

Fig. 2. Base support for truss-out scaffold (Adopted from Buildings Department, 2006).

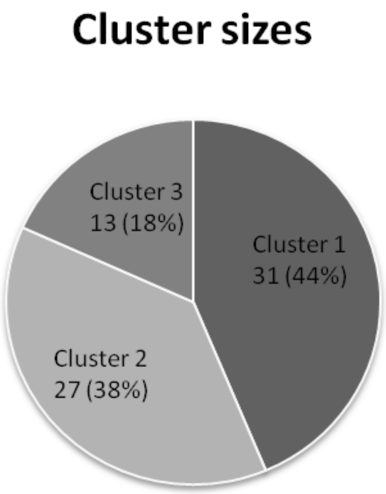

Fig. 3. Frequency distribution of the three clusters of fall from height fatal cases.

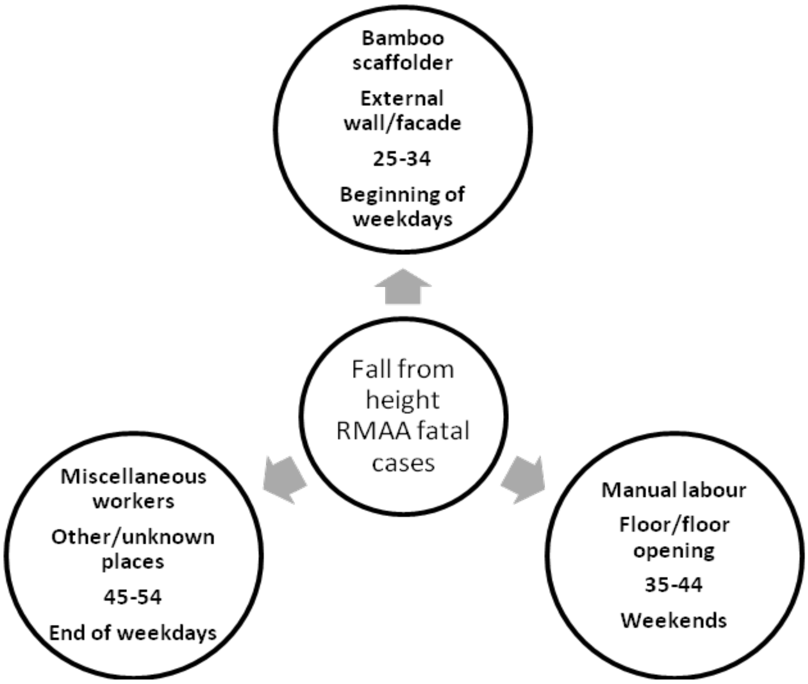

Fig. 4. Three clusters of fall from height RMAA fatal cases.

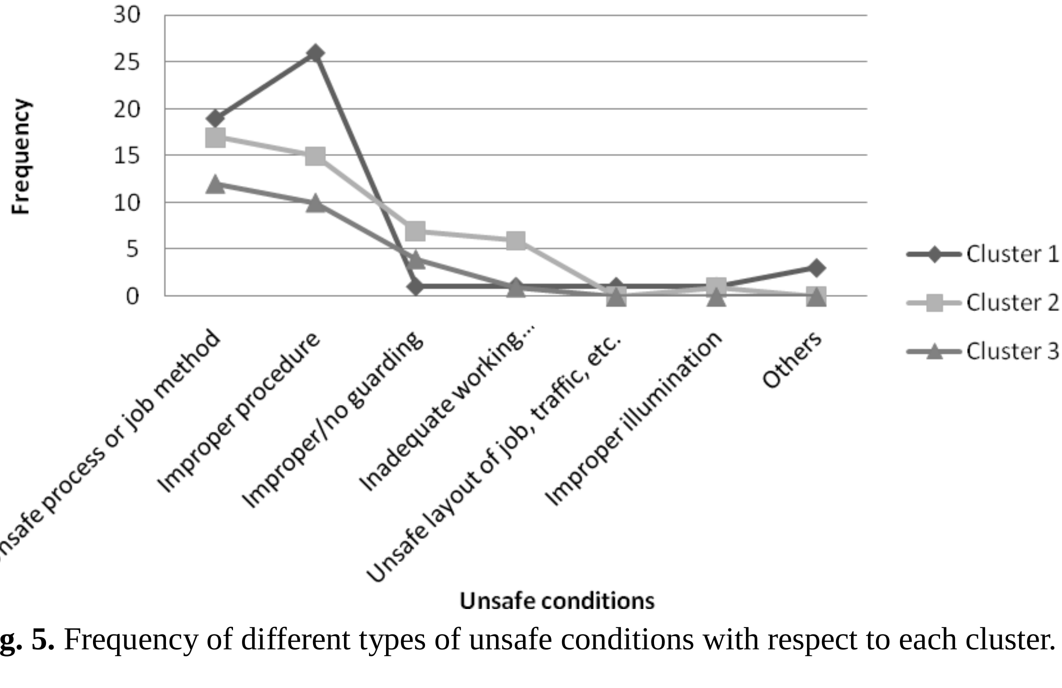

Fig. 5. Frequency of different types of unsafe conditions with respect to each cluster.

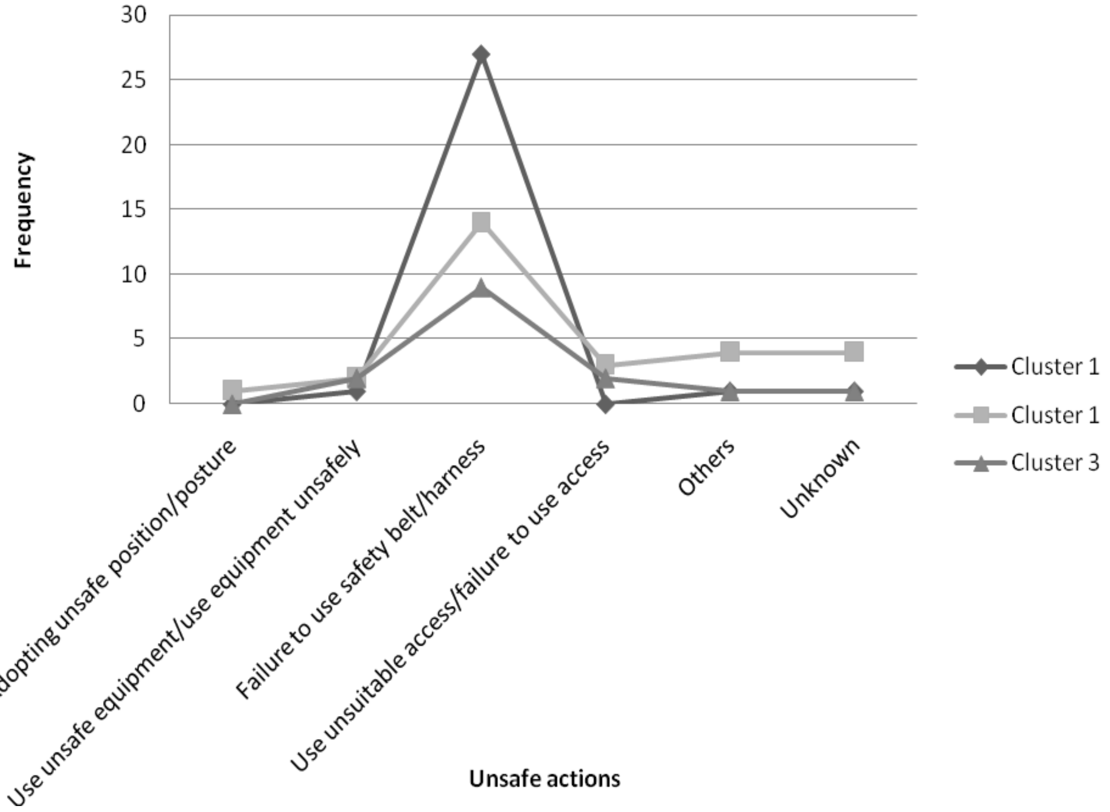

Fig. 6. Frequency distribution of unsafe actions with respect to each cluster.

Table 1

Gross Value of Construction Work at Current Market Prices (1998–2010). (Unit: HKD Million at Current Prices [USD 1 = HKD 7.8]).

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	**2010**
Residential (A)	48,761	56,225	51,920	41,774	36,503	28,612	20,085	16,945	15,518	16,064	20,613	22,804	22,381
Non-residential (B)	33,866	20,455	17,407	16,026	16,502	18,243	17,425	17,060	14,161	17,289	17,287	16,938	18,206
Civil Engineering (C)	19,349	16,873	20,583	24,491	21,358	20,710	19,044	14,686	12,311	10,123	10,934	12,516	20,388
Total Construction Investment (A+B+C)	101,975	93,553	89,910	82,290	74,362	67,564	56,553	48,691	41,990	43,476	48,834	52,258	60,974
Repair, Maintenance, Minor alteration and Addition (D) †	31,341	32,884	32,161	31,696	31,638	31,468	36,618	42,160	48,240	49,390	50,765	48,686	49,966
Total Construction Market (A+B+C+D)	133,316	126,437	122,071	113,986	106,000	99,032	93,171	90,851	90,230	92,866	99,599	100,944	110,940
Percentage of RMAA Works to Total Construction Market [D/(A+B+C+D)*100]	23.5%	26.0%	26.3%	27.8%	29.8%	31.8%	39.3%	46.4%	53.5%	53.2%	51.0%	48.2%	**45.0%**

Note. Data source from Report on the Quarterly Survey of Construction Output, Tables 1A and 3, Census and Statistics (CS&D) Department, Hong Kong.

† The CS&D named this figure as "Locations other than sites" which refers to "Works at locations other than construction sites includes minor new construction activities and renovation works at erected buildings and structures; and electrical and mechanical fitting works at locations other than construction sites."

Table 2

Industrial Accidents of the Construction Industry.

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	**2010**
(a) All reported construction accidents*	19,588 (56)	14,078 (47)	11,925 (29)	9,206 (28)	6,239 (24)	4,367 (25)	3,833 (17)	3,548 (25)	3,400 (16)	3,042 (19)	3,033 (20)	2,755 (19)	2,884 (9)
(b) Accident rate per 1,000 workers	247.9	198.4	149.8	114.6	85.2	68.1	60.3	59.9	64.3	60.6	61.4	54.6	52.1
(c) All reported accidents in RMAA Works*	3,510 (7)	3,328 (10)	3,402 (12)	2,582 (4)	1,925 (10)	1,485 (8)	1,454 (6)	1,509 (12)	1,697 (9)	1,524 (6)	1,557 (6)†	1,379 (9)†	1,422 (6)†
Percentage of RMAA accidents to all reported construction accidents [(c)/(a)]	17.9%	23.6%	28.5%	28.0%	30.9%	34.0%	37.9%	42.5%	49.9%	50.1%	51.3%	50.1%	49.3%
Percentage of fatal accidents in RMAA works to all fatal accidents in the construction industry	12.5%	21.3%	41.4%	14.3%	41.7%	32.0%	35.3%	48.0%	56.3%	31.6%	30.0%	47.4%	**66.7%**

Note. Data from Labour Department of Hong Kong (2008b, p. 3; 2010) and Legislative Council (2011a, 2011b). * Figures in brackets denote the number of fatalities. † Statistics for fatal RMAA accidents in 2008-2010 were collected from newspaper archives.

Table 3
Types of RMAA accidents in Hong Kong.

Types of RMAA accidents	Frequency	Percentage
Fall of person from height	74	62%
Contact with electricity or electric discharge	20	17%
Contact with moving machinery or object being machined	3	3%
Trapped by collapsing or overturning object	5	4%
Asphyxiation	4	3%
Slip, trip or fall on same level	1	1%
Trapped in or between objects	4	3%
Striking against or struck by moving object	1	1%
Exposure to or contact with harmful substance	1	1%
Struck by falling object	5	4%
Others	1	1%
Total	119	100%

Table 4
Cross-tabulation analysis of the clusters.

Variable	Category	Cluster 1 (*n* = 31)	Cluster 2 (*n* = 27)	Cluster 3 (*n* = 13)	Total (*N* = 71)
Time	08:00-12:00	9	9	3	21
	12:01-14:00	4	3	4	11
	14:01-18:00	***17***	***13***	***5***	35
	Others	1	2	1	4
Day*	In the beginning of weekdays	***13***	10	0	23
	In the middle of weekdays	6	6	1	13
	In the end of weekdays	7	***11***	5	23
	Weekends	5	0	***7***	12
Season	Spring	5	6	1	12
	Summer	***15***	***9***	***6***	30
	Autumn	7	4	3	14
	Winter	4	8	3	15
Age*	≤ 24	5	0	4	9
	25-34	***13***	1	0	14
	35-44	5	2	***6***	13
	45-54	4	***13***	3	20
	≥55	4	11	0	15
Trade*	Labour	2	2	***8***	12
	Painter and decorator	2	3	0	5
	Building services/ E&M worker	2	2	3	7
	Bamboo scaffolder	***24***	0	0	24
	Miscellaneous	1	***20***	2	23
Body part injured	Multiple locations	***23***	***14***	***7***	44
	Skull/scalp	8	13	6	27
Injury nature	Multiple injuries	***23***	***15***	***8***	46
	Contusion and bruise	7	11	5	23
	Concussion	0	1	0	1
	Others	1	0	0	1
Place*	External wall/facade	***31***	8	3	42
	Floor/floor opening	0	8	***6***	14
	Roof/top of building	0	1	4	5
	Others	0	***10***	0	10
Agent	Ladder	2	4	2	8
	Scaffolding/gondola	***24***	5	2	31
	Others	5	***18***	***9***	32
Type of work	Material handling	0	1	1	2
	Manual work	0	4	2	6
	Electrical wiring	0	2	2	4
	Water pipe fitting	0	2	0	2
	Air-conditioner installation	2	2	2	6
	Painting	1	4	0	5
	Demolition work	3	3	***3***	9
	Bamboo scaffolding	***24***	0	0	24
	Others	1	***9***	***3***	13
Safety equipment	Not provided	***20***	***15***	***10***	45
	Provided but not used	0	4	1	5
	Provided and used	9	2	0	11
	Unknown	2	6	2	10
Employment	Employee	***22***	***19***	***9***	50
	Self-employed	8	8	2	18
	Illegal migrants	1	0	2	3

Note. Numbers in bold and italics represent the mode of the categories. *Key features used in the classification of clusters.

Table 5

Comparing the age distributions of bamboo scaffolders in RMAA fatalities with registered bamboo scaffolders in Hong Kong.

	Fall from Height fatalities of bamboo scaffolders in RMAA works		Registered bamboo scaffolders in Hong Kong (Construction Workers Registration Authority, 2011)	
Age	Frequency	Percentage	Frequency	Percentage
Below or equal to 24	5	21% *(21%)*	33	2% *(2%)*
25-34	9	37% ***(58%)***	329	20% ***(22%)***
35-44	4	17% *(75%)*	384	23% *(45%)*
45-54	2	8% *(83%)*	580	36% *(81%)*
55 or above	4	17% *(100%)*	306	19% *(100%)*
Total	24	100%	1632	100%

Note. Numbers in italatics refer to cumulative values.