

COMPARATIVE STUDY ON SAFETY AND APPLICATION OF BAMBOO AND METAL SCAFFOLDING IN HONG KONG

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Introduction

Finance, real estate, tourism and manufacturing are the four major industries in Hong Kong. Construction industry, which relate to the real estate industry, has been playing an important role in the economy of Hong Kong. Being an essential means and equipment for construction, scaffolding provides workers with working platform, safe access and protection.

It is because of its lightweight, skillful workers and especially its low price, the bamboo scaffolding has the advantages in construction bidding process. However, the disadvantage is its low strength, inflammableness, irregular shape, changeable nature and uncertain quality that badly influence the construction safety and quality as well as companies' image. The metal scaffolding overcomes those shortcomings of bamboo scaffolding, and it also has such advantages as easy for erection, safe and reliable, and meeting the demand of standardization and automation in construction industry. Now, more and more contractors are considering to use it, although the price is much more expensive than bamboo scaffolding. Therefore, metal scaffolding remains in inferior position to their competitor. Since bamboo and metal scaffolding have their own advantages and disadvantages, both have been argued as being better for Hong Kong construction industry.

It is recorded that three quarters of the construction fatal accidents occurred in Hong Kong are falls from height. D. Mak ^[1] pointed out that among 41 fatal accidents occurred on construction sites in 1997s, 20 were related to falls, in which 6 (30 %) were workers falling from bamboo scaffolding ^[2]. K.W. Wong ^[3] studied the management of bamboo scaffolding and provided relevant useful information for carrying out supervision and inspection of works associated with bamboo scaffolding and to improve the safety of bamboo scaffolding in Hong Kong. W. Y. Fu ^[4] indicated that bamboo scaffolding provides a flexible, practical and economical means of support. He also pointed out that there was no specific regulations concerning design, calculation and drawing of bamboo scaffolding in Hong Kong and that qualification of structural design and construction of bamboo scaffolding would be depended on the experience of scaffolding workers. However, in many aspects of the safety, it need to be improved. S.L. Chan ^[5] suggested a computerized method to design and analyze bamboo scaffolding. Y. Y. Wong ^[6] and J. Chow ^[7] discussed the requirements of laws and regulations for inspection and supervision of bamboo and metal scaffolding and they had suggested a method to improve the current situation. However, there are seldom research studies on comparing safety and future application of the two kinds of scaffoldings.

Objectives of this study are to synthetically and systematically evaluate the application of two kinds of scaffolding by investigating and comparing their safety performance, economical effectiveness and influences on other major factors, and to explore the development trend of scaffolding in Hong Kong and the countermeasures the government and contractors should consider.

Research Methodology

Figure 1 shows the research framework of this project. Safety performance and economical effectiveness are the emphasis in this research framework. As temporary structures, scaffolding is provided by suppliers, rented by contractors, and erected and dismantled by workers. Workers and the scaffolding form a human-environment system in which safety is the emphasis. Contractors and suppliers form a market system in which economic issues are the emphasis.

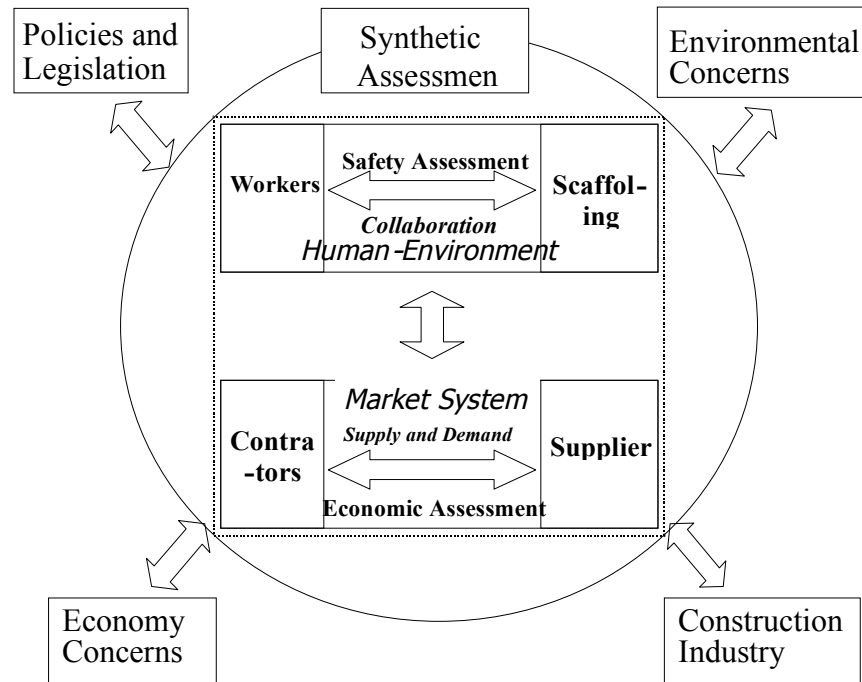


Figure 1 Research Frame

Comparison on safety performance

Scaffolding is erected by scaffolders and its quality is directly influenced by scaffolders' skills. Besides, scaffolding structure is the working platform for workers working on it and this working condition would influence the safety and quality of these workers' performance. The contractors are responsible for the management of erecting, dismantling and carrying out daily maintenance of scaffoldings. In this human-environment system, the safety of the two kinds of scaffolding will be assessed by hazard analysis, analysis hierarchy process and experimental psychology based method.

Hazard analysis ^[8] is originated from a method adopted by America Atomic Energy Commission. Its principle is to evaluate the risk of an event by comprehensively analyzing the probability of occurrence and the consequences of this event. The process is to decompose a complex safety assessment problem into several sub-problems that can be evaluated independently, and then to assess these sub-problems independently, and finally to sum up results of sub-problems to an overall conclusion of the original problem. Thus, the risk index of an event can be obtained through following functions:

$$H_i = L \times E \times C$$

H_i — risk index of a factor

L — failure probability of a factor

E — accident probability of a failed factor

C — possible outcome of a failed factor

$$H = \sum_{i=1}^n H_i$$

N — number of factors

Analytic Hierarchy Process (AHP) ^[9] has been used to analyze complex decision-making problems in social, political, economical and technological field. Its solution process is as follows. 1) A complex problem is structured by decomposing it into a hierarchy with enough levels to include all factors to reflect the goals and concerns of the decision maker; 2) Elements are compared in a systematic manner using the same scale to measure their relative importance, and the overall priorities among the elements within the hierarchy are established; 3) The relative standing of each alternative with respect to each criterion element in the hierarchy is determined using the same scale and; 4) The overall score for each alternative can then be aggregated, and the sensitivity analysis can be performed to see the effect of change in the initial priority setting, while the consistency of comparison can be measured.

The experimental psychology ^[10] based test uses multi-channel physiology equipment to measure the influence of scaffolding conditions on human beings by measuring mental pressure and the level of nervousness caused by different working conditions (bamboo scaffolding and metal scaffolding). The authors developed this method to provide an objective tool for assessing working conditions' impact on workers' behaviors, especially on safety behaviors.

Comparison on economical effectiveness

Rents of scaffoldings are determined by its cost and market share, and directly influence the cost of a construction project as well as contractors' profit. The lifetime analysis of net present value and the payback period of the two kinds of scaffoldings is conducted from both suppliers' and contractors' point of view. After major economic indexes were defined based on the first survey in the summer of 2000, a questionnaire survey was conducted, and the static cost and dynamic cash flow are analyzed.

Synthetic comparison

Safety and economy are two correlated factors that determine contractor's choice of scaffoldings. The study takes the two major aspects and other factors such as construction quality and company's images into consideration to assess these two kinds of scaffoldings synthetically, so as to provide fundamental information for the government to enact relevant policies and for contractors to choose scaffoldings.

Questionnaire Survey and Analysis

Four sets of questionnaires and a survey on economical issues were developed. 20 pieces of questionnaire for expert were distributed, in which 17 pieces were replied effectively. 400 pieces of questionnaire for workers were distributed, in which 238 pieces were replied and 180 pieces were effective. 28 pieces of questionnaire for safety officers are distributed, all of which were replied effectively. 8 suppliers were surveyed, 10 construction sites were visited, and 30 project managers were inquired. Based on the outcome of these questionnaires and surveys, the safety performance and economic effectiveness of bamboo and metal scaffolding were studied, compared and analyzed by above mentioned methods.

Safety performance

By hazard analysis, the risk of accident in metal scaffolding is found to be 0.32 and that in bamboo scaffolding is found to be 0.68. By AHP, the risk of accident in metal scaffolding is found to be 0.39 and that in bamboo scaffolding is found to be 0.61. The safety assessment by the two methods results in consistent conclusions. Figure 2 shows the risk index of every factor by hazard analysis. The result of the experimental psychology based test indicates that the workers in bamboo scaffolding are easier to get nervous, tired, and to act erratically, all of which are easy to make accidents happen ^[10].

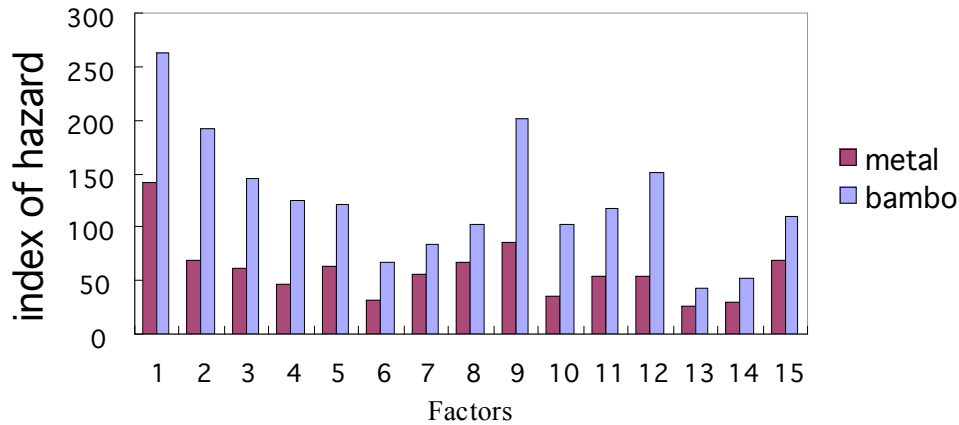


Figure 2 Hazard indexes of factors

1) broken putlog or lacking in putlog; 2) flabby or broken node; 3) rotten member of scaffolding; 4) broken member of scaffolding; 5) without or broken working platform; 6) without or broken toeboard; 7) without or broken guardrail; 8) broken bracing; 9) overload; 10) hit by downfallen object; 11) without safety belt; 12) without place the safety belt fasten; 13) without safety helmet; 14) tired and distracted; 15) violate operation regulation

Table 1 shows the safety risk ranking by AHP. The results of questionnaire survey also indicate that the safety knowledge is very important. The professional skill and safety knowledge provide workers with the capability to identify hazard and to decrease unsafe behaviors. It is also found that the safety training should pay more attention on the putlog, bracing, and so on to ensure workers to understand the consequences of destroying these parts of scaffolding. It is also very important to improve the working conditions of scaffolding because the spacious and neat working platform could decrease workers' nervous emotions and unsafe behaviors. Providing better working platform, safety belt and places for fastening safety belt could improve company's safety performance. Discovering and repairing destroyed parts in time will decrease the unsafe condition.

Economical effectiveness

The cost of bamboo scaffolding is low and the initial investment of metal scaffolding is relatively higher, the rent of metal scaffolding is generally 2~2.5 times of that of bamboo scaffolding. The payback period of bamboo scaffolding is shorter and the risk is low, while the payback period of metal scaffolding is longer and the risk is higher. For the metal scaffolding, the rent could be decreased if there is a stable market demand. The integral elevated scaffolding system, which has been widely used in China, has such advantages as short payback period, low risk and less material consumption.

Factors	Hierarchy	Factor and weight					Weight
	B	Human (B1)		Condition (B2)			
		0.656		0.344			
	C	Physic and mentality (C1)	Knowledge (C2)	Material (C3)	Erecting and dismantling (C4)	Destroyed by outside action (C5)	
		0.485	0.515	0.382	0.383	0.235	
B*C	0.318	0.338	0.131	0.132	0.081		
Human	Degree of fatigue (D1)	0.601					0.19
	Working space (D2)	0.399					0.13
	Professional skill (D3)		0.498				0.17
	Safety knowledge (D4)		0.502				0.17
Condition	Selecting material (D5)			0.500			0.07
	Maintenance (D6)			0.500			0.07
	Design (D7)				0.594		0.08
	Experience (D8)				0.406		0.05
	Environment (D9)					0.455	0.04
	Human (D10)					0.545	0.04

Table 1 Safety risk ranking

Synthetic comparison

Metal scaffolding is better than bamboo scaffolding when synthetically comparing their safety performance, economic effectiveness, as well as quality, company's images and so forth. The synthetic assessment value is 0.87 for metal scaffolding and is 0.67 for bamboo scaffolding. Metal scaffolding is higher in price, and the cost difference between the two kinds of scaffolding will increase dramatically with the increase of the height of building. The rent of metal scaffolding wouldn't decrease largely on the basis of the information from suppliers. The integral elevated scaffolding system gains excellent synthetic assessment result and its cost is relatively lower. At the same time, the unit cost will decrease with the increase of the height of building. The assessment, synthetically considering safety, economy and other factors indicates that the metal scaffolding has advantages over bamboo scaffolding and that integral elevated scaffolding would have a bright prospect in Hong Kong because of its safety performance and reasonable cost.

CONCLUSION

This paper briefly introduced findings of a comparison study between metal and bamboo scaffolding on their safety performance and economical effectiveness. It is found that metal scaffolding is much safer than bamboo scaffolding, while bamboo scaffolding is much cheaper. To consider both safety and economic factors synthetically, it is found that contractors should be encouraged to use metal scaffolding for safer construction.

Acknowledgements

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