13th International Conference on
Steel, Space and Composite Structures
31 January - 2 February 2018, Perth, Australia

STEEL CONSTRUCTION IN HONG KONG: SUPPLY CHAIN AND COST ISSUES

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Keywords: Structural steelwork, Cost comparison, Case study, Construction cost

Abstract. *The application of steel structures for building works grows worldwide, but not in Hong Kong. The number of steel framed buildings so far is less than 2% of all the buildings. For many years the local industry has evolved to the use of reinforced concrete as the main building structure material with proven efficiency and competitiveness. Cost issue has long been a primary hurdle to the adoption of steel structures in the local construction industry. The current study aims to address relevant costs issues concerning structural steelworks in Hong Kong. First, structural steel supply chain issues were identified based on data information obtained from desktop search and relevant stakeholders. Then a case study on a hotel building project was analysed to explore the reasons why the owner finally withdrew the steel composite structure. The findings indicate that the construction cost of structural steelwork is inevitably high, and the construction of steel-framed structure does not have a significant benefit for improving construction program. These issues make steel construction unfavourable in Hong Kong. Towards a wider use of structural steel in construction, efforts should be made to improve construction program thereby bringing early completion of the project and early return on investment.*

1 INTRODUCTION

The application of steel structures for both building and infrastructure works grows worldwide, but not in Hong Kong. The number of steel framed buildings so far is less than 2% of all the buildings[1]. Reinforced concrete structures are still dominating building construction in Hong Kong with proven efficiency and competitiveness. Structural steelworks are usually adopted for purpose-built projects, such as super-high rise and long span structures. Structural steel is not widely used in the local construction industry because it is not efficient and cost-feasible for common building projects[2].

The main problem that drivers the research questions and issues investigated is why steel or composite structures are generally not cost-efficient in Hong Kong as compared with reinforced concrete (RC) structures. This study aims to explore the cost issues related to structural steelworks. Cost components and factors affecting the cost of structural steelworks are reviewed. Data collection on unit price of steel members and cost components offered by different stakeholders is conducted. A case study analysis is then conducted to compare the construction costs between steel-RC composite structure and RC structure.

2 LITERATURE REVIEW

Construction supply chain acts as a network of interrelated processes designed to achieve improved cost performance and satisfied clients within a project[3-4]. Hong Kong is a net importer of steel because of a lack of upstream players, and almost all steel businesses are traders and wholesalers. Within the supply chain of a structural steel project in Hong Kong, major customers include owner, main contractor, subcontractors, steel fabricator, steel trader, steel supplier, and various consultants specialized in architectural and structural designs, and electricity and maintenance (E&M) and other services. Supply chains can significantly affect the total construction cost as each actor within the supply chain makes a profit.

Sarma and Adeli[5] divided the total cost of a steel structure into nine different cost components, including cost of planning and design, cost of preparing the project site, material cost, fabrication cost, transportation cost, storage cost, erection cost, cost of machinery, and maintenance cost. The cost of steel construction can be further classified into the four categories, namely, material costs, fabrication cost, erection cost, and others[6]. Material cost includes any structural steel products and waste materials. Fabrication cost consists of labour cost for shop drawing and fabrication works, other costs for shipment and subsequent erection on site, and overhead and profit. Erection cost is composed of labour cost of erection, plant cost, and others to unload, lift, place and connect the structural steel components, including overhead and profit. The fourth category includes additional costs associated with risk, the need for contingency, and the schedule requirements of the project. For a typical structural steel building in the U.S., material, fabrication, erection, and other costs in broad term are 25%, 35%, 25%, and 15%, respectively, of total construction cost[6]. For a steel frame of a typical multi-storey office building in the U.K., raw materials, fabrication, erection, fire protection, and others account for 30-40%, 30-40%, 10-15%, 10-15%, and 3%, respectively[7].

Four major facets could affect initial cost estimation of steel frames during the design stage, namely, building function and facilities, location and site constraints, market conditions, and procurement route[8]. Sarma and Adeli[5] identified five main factors that influence the total cost of a structure. These are: cost of the rolled sections, number of different section types, weight of rolled sections, number of connections, and geographic location of the project site. While the weight of a structure constitutes a significant part of the cost, the costs of members of a structure are not necessarily proportional to their weights[5]. The costs of structural steel materials can be affected by different structural shapes, the size and the grade of steel, special orders on uncommon sections, materials imported from other countries, and charges from steel fabricators[5]. McNamara[7] pinpointed that 11 key cost drivers for commercial buildings, including core options, floorplate configuration, repetition, robustness, vibration performance, structural zone, service integration, erection of steelwork, fire protection, logistics and programming, and market influences. The weight of steel used undoubtedly influences the material cost. From a weight viewpoint minimum weight design may be chosen. But such a design often has members of many different cross-sections, resulting in the complexity of fabrication[9]. Although using similar cross-sections cause a weight penalty, it may ultimately reduce fabrication costs because these sections are easier to detail, fabricate, and erect[9-10].

Zhong and Wu[11] compared the economic sustainability, environmental sustainability, and constructability between RC- and steel-projects. They found that RC-framed buildings outperform steel-framed buildings in structural costs, maintenance costs, and financial costs, whereas steel-framed buildings outperform RC-framed buildings in increased area, flexibility of internal space, recycling rate, recyclability, waste rate, water consumption, labour saving, construction duration, and construction quality. Achulitz et al.[12] agreed that using steel frame could increase additional 5-8% usable area instead of RC. Andrews[13] found that foundation cost of steel-framed buildings were cheaper than that of RC-framed buildings. Using steel could also minimize the use of materials and waste[14]. These financial benefits may afford market opportunities for wider adoption of steel structures.

3 RESEARCH METHODOLOGY

The above literature review offers a guideline for data collection design. Given the components of construction cost, material, fabrication, erection, and other relevant costs of structural steelworks were gathered. The current study adopted a mixed approach (Figure 1) to explore the key cost issues of structural steelworks in the Hong Kong construction industry. A variety of data sources were acquired from the statistics department, business reports, and the local construction stakeholders. A case study was then performed to compare the costs between the reinforced concrete (RC) and the steel-reinforce concrete composite structures. A qualitative approach was then employed to identify the key cost issues concerned about by relevant stakeholders.

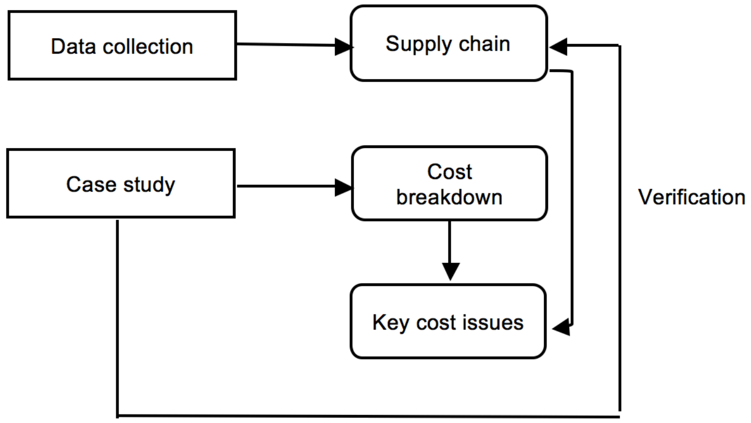


Figure 1: Research methodology

3.1 Data collection

The Hong Kong Merchandise Trade Statistics - Imports released by the Census and Statistics Department (C&SD) illustrates the value and annual quantity of imports of commodity including base metal and structures of iron or steel. The sell-out prices of the materials were requested from the four local stockists. The average wholesale price of building materials was also collected from the C&SD. Construction rates for selected materials were extracted from the Schedule of rates for term contracts for building works (volume 1) for builder's work by the Architectural Services Department. They are based on lump sum fixed price contract rates exclusive of preliminaries and contingencies. On this basis, the approximate costs of selected materials from imports, steel stockists, fabrication, to erection on site were produced. Furthermore, the semi-structured interviews were conducted with 4 steel stockists, 5 main contractors and 4 steel specialist contracts regarding steel supply chain issues.

3.2 Case study

A private developer initially intended to adopt a steel composite structure for building a new hotel (at height of 102 m, GFA of 32,000 m^2, and 24-storey, about 700 rooms). However, upon the completion of a feasibility study with cost estimation, the idea was withdrawn. Instead, a traditional RC structure was adopted. The construction costs and project duration of the original steel composite structure and the current RC structure were requested from the developer. An interview was carried out with the client, the in-house contractor and quantity surveyor to explore the reasons behind their decision-making on changing the structural design.

4 RESULTS

4.1 Supply chain

There are two steel delivery routes in the local industry. Rout (a) is a common work practice as the local steel stockists have quality control on the Class-One materials and thereby reducing testing logistics of buyers, while the route (b) is usually form large quality transaction (Figure 2).

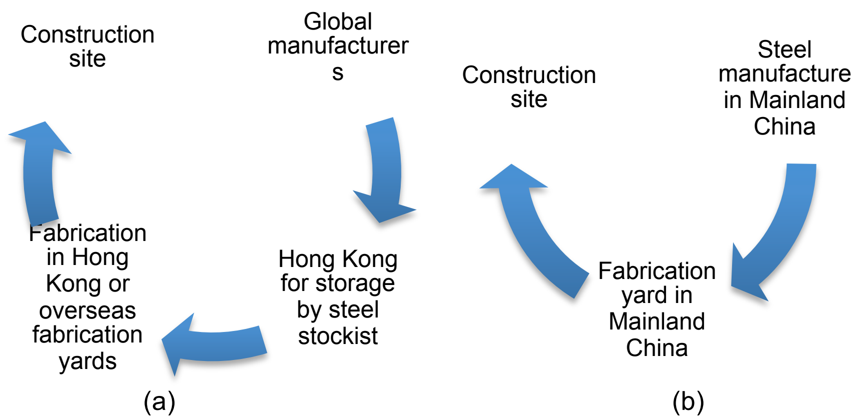


Figure 2: Current work practice to deliver steel materials

The original places of open sections include Mainland China, Taiwan, Japan, Korea, and Thailand (Figure 3a). The proportion of import from China increased in recent years. Steel plates and galvanized steel plates were mainly from China and Japan, respectively. Steel structures or parts of structures were mainly from Mainland China. This implies that fabrication works are mainly carried out in Mainland China. Steel stockists indicated that H-beams were mainly from Korea, Japan, Taiwan, and Mainland China (Figure 3b). H-beams produced in Mainland China commonly use the National standards, while Hong Kong adopts the European standards. It is not easy for Chinese factories to replace the machine parts to produce a wide range of sizes for H-beams under the Euro codes. The source of materials depends on the design code and specifications. The Euro/BS code is generally adopted in Hong Kong. Although the Buildings Department (BD) accepts other codes such as JIS, CN (according to the Code of Practice for the Structural Use of Steel), the use of design codes other than BS is still limited in the local industry.

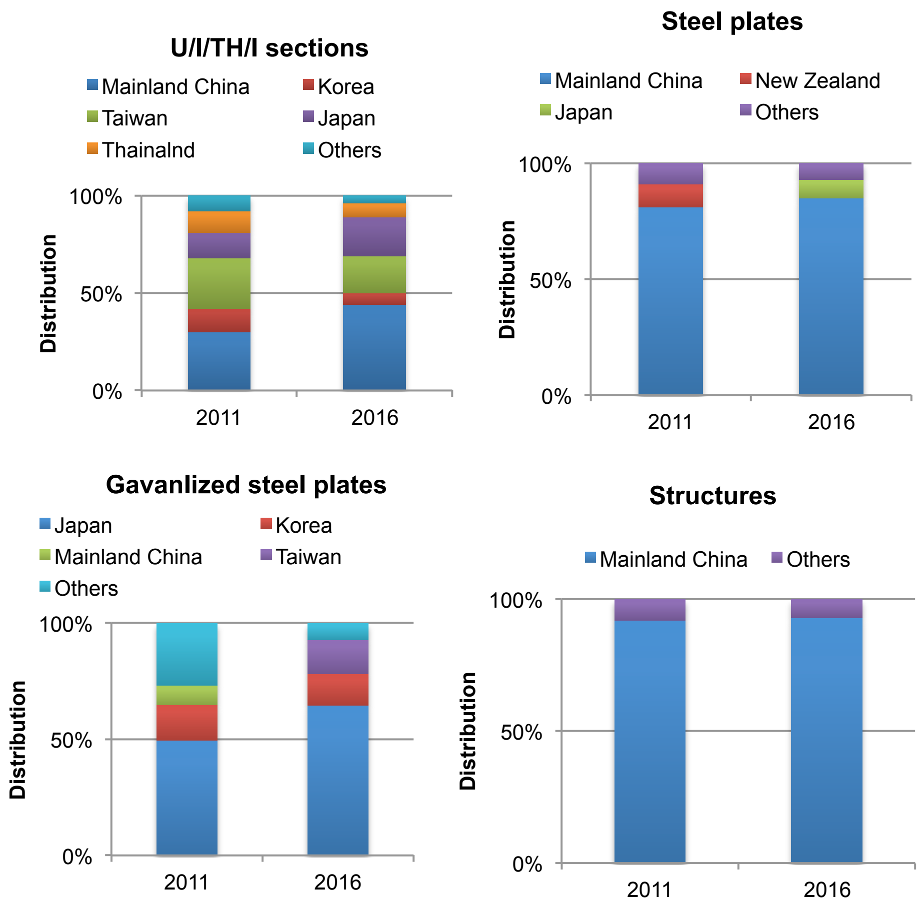
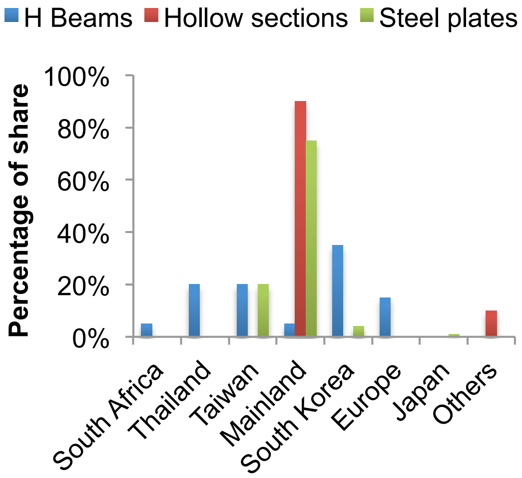


Figure 3a: Distributions of steel materials by import countries (source: Hong Kong Merchandise Trade Statistics - Imports, Census and Statistics Department)



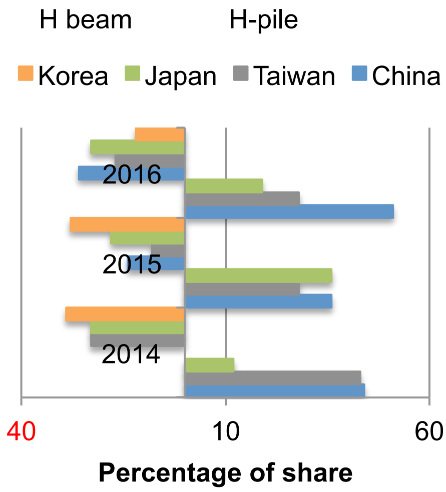


Figure 3b: Distributions of steel materials by import countries (source: Steel stockists)

Although there are some small fabrication yards in Hong Kong, most of steel structures are fabricated outside Hong Kong because of a shortage of land resources. Hence, the import quantity of steel structures could be a reference to the approximate quantity of steel structures consumed in construction. Figure 4 illustrates that the annual import quantity of steel structures was around 0.2~0.3 million ton.

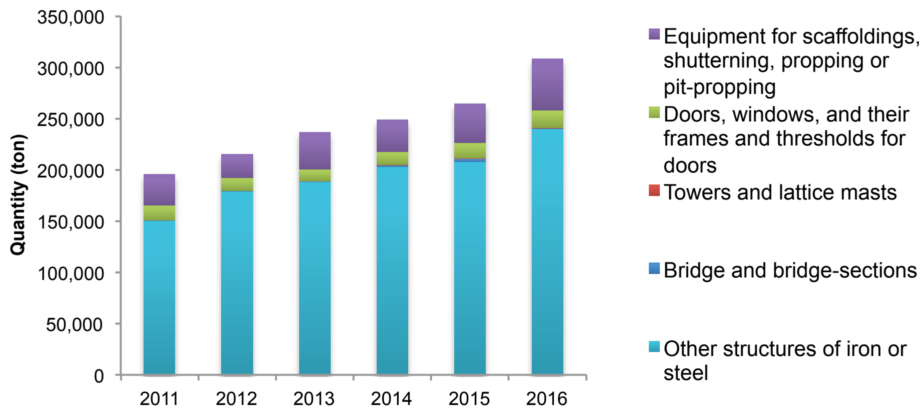


Figure 4: Quantity of imported structures and parts of structures, of iron or steel (source: Hong Kong Merchandise Trade Statistics - Imports, Census and Statistics Department)

Figure 5a illustrates the unit price of steel materials during the period of 2014 – 2016 offered by the local steel stockists. The price of rebar decreased faster (i.e., 38%) than that of steel materials (i.e., 7%~25%) over the past three years. The prices of galvanized steel plates kept a small fluctuation. Figure 5b shows the average wholesale prices of steel materials during the period of 2014 – 2016 released by the C&SD. There was a remarkable decreasing trend in the average wholesale price of rebar (i.e., 24%), while the price of galvanized steel materials nearly remained constant (i.e., 1%~9%). The import price of steel structures was relatively stable (i.e., HK$ 8000-9000 per ton) according to the C&SD.

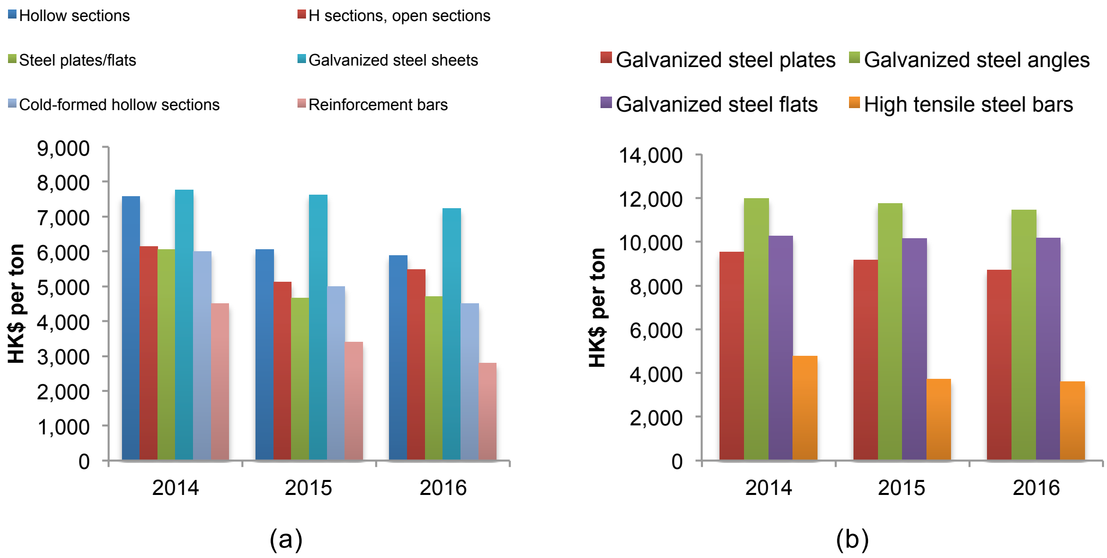


Figure 5: Average unit price of steel materials provided by (a) steel stockists, (b) Census and Statistics Department

For non-residential public building works according to the Architectural Services Department, there was a tendency towards a slightly increasing the construction rate of permanent structural steelworks (i.e., 2%) from 2010 to 2016. Particularly, the contract rate for "Fix" work increased, whereas it slightly declined in "Supply" work. The percentage of "Fix" and "Supply" works accounted for 55% and 45% of total construction rate, respectively. The reported construction rate of structural steelworks roughly ranged between HK$ 24,000 to 28,000 per ton. This figure was consistent with that offered by the main contractors and steel specialist contractors who indicated that the current rate was HK$ 20,000 to 30,000 per ton. It can escalate to HK$ 40,000 ~HK$ 50,000 per ton regarding some specific project features according to their shapes, member sizes, and design requirements. Figure 6 depicts the distribution of cost components of the rate of structural steelwork provided by the contractors. Material and fabrication costs account for 45%~50% of structural steelworks. The costs of cementitious coating and fire retardant paint (60-min) are around HK$ 300 per m^2 and HK$ 1,200 per m^2, respectively.

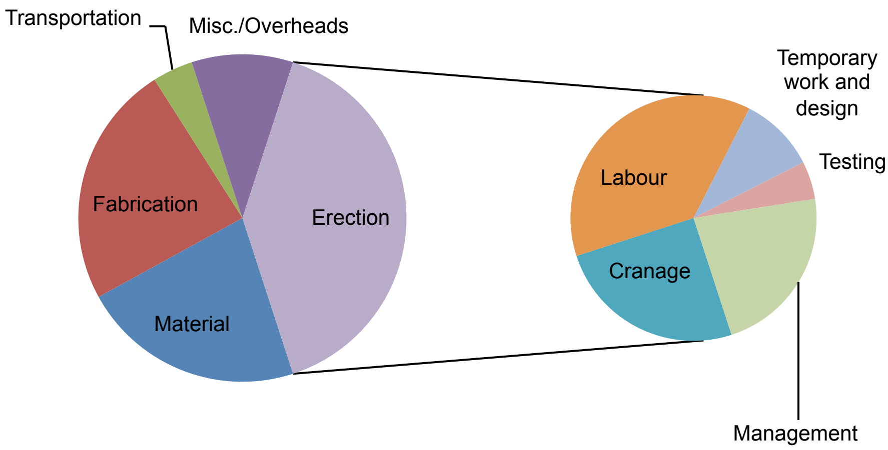


Figure 6: Cost components of the rate of structural steelwork

4.2 Cost issues in the case study

The original steel composite design adopted a RC core wall with structural steel frame and cross bracing shear wall. The current RC design utilizes a RC core wall and shear wall. The construction period for steel composite structure was one month shorter than RC. However, the approval procedure for steel composite design was more time-consuming than RC one. In total, the project duration of steel composite structure was half of a month shorter than RC. From the perspective of the client, steel composite design does not have a significant benefit for improving construction program.

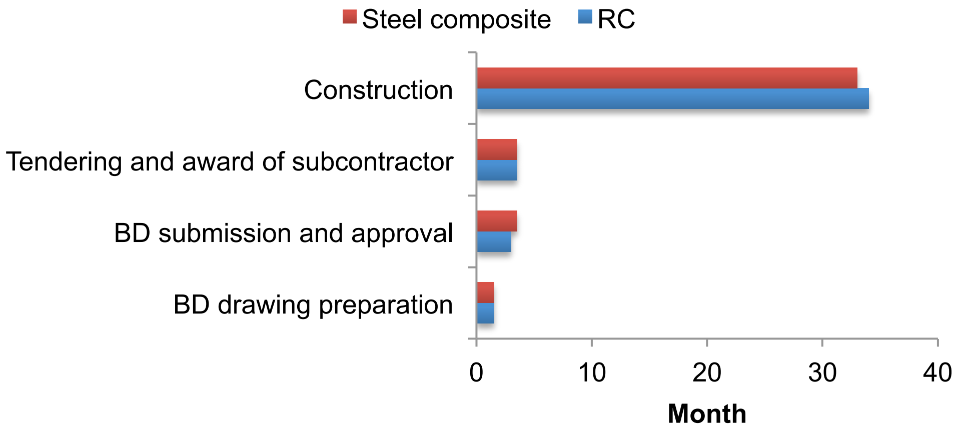


Figure 7: Project duration

The construction costs of RC and steel composite structures were HK$ 1,400 million and HK$ 1,600 million, respectively. The cost of superstructure of steel composite doubled that of RC (Figure 8). Accordingly, the cost per unit area of RC and steel composite structures were HK$ 394 per ft^2 and HK$ 890 per ft^2, respectively, indicating that steel composite bore extra HK$ 496 per ft^2. Table 1 depicts the cost breakdown of structural steel, in which structural steelwork and fire enclosure accounted for 74% and 10%, respectively. As there were 4,123 ton steel materials to be used, the rate of structural steelwork was HK$ 36,150 per ton.

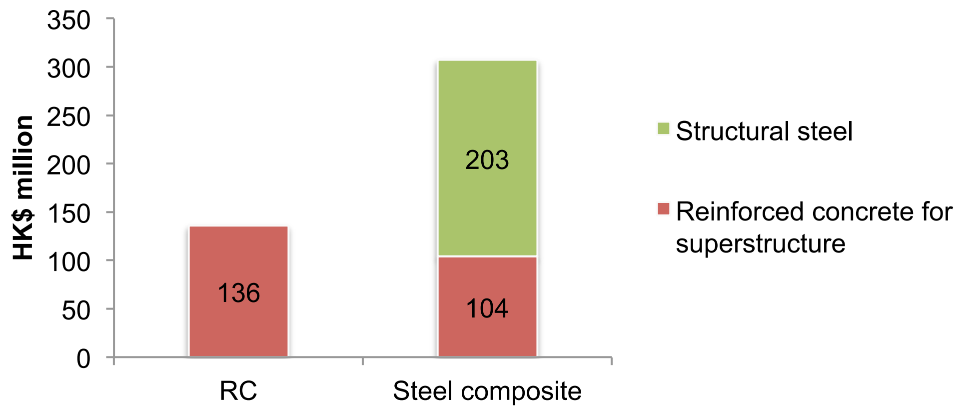


Figure 8: Cost of superstructure

Item	Cost (HK$ million) and percentage
- Structural steelwork	149 (74%)
- Rebardek® steel deck	26 (12%)
- Fire enclosure	20 (10%)
- Sound insulation	8 (4%)
TOTAL	203 (100%)

Table 1: Cost breakdown of structural steel

The client indicated that the cost issue was the predominant obstacle to the adoption of steel frame structure in this project. First, the construction cost of steel composite structure was dramatically higher than RC one. Material cost of steel sourced from Japan was much higher than that of RC. Rental cost for a luffing crane was considerable for vertical transportation and installation works. Land rent cost for temporary offsite storage yard was also prohibitive. Curtain wall external cladding that is compatible with steel structure could push up construction cost as well. Second, while the project duration was 0.5 month shorter in composite structure than RC, it did not contribute to a benefit of early return on investment. Steel composite might take longer time for preparation works, e.g., structural design, design approval, award of a tender, and material procurement. It might be also time consuming during the finishing work phase, as sometimes structural steel is not compatible with E&M works. Overall, the interviewees concluded that steel composite design was cost inefficient for a 24-storey hotel, whereas it might be more cost-efficient for super high-rise buildings in Hong Kong, such as the International Commerce Centre.

5 DISCUSSION AND CONCLUSIONS

The demand for structural steelworks is not strong in Hong Kong during the past several years in terms of 0.2~0.3 million ton per year of steel structures consumed in Hong Kong. The cost of the supply (including raw material and fabrication) of structural steelwork is prohibitive. The rate of the decrease in unit price of structural steel material was slower than that of rebar during the past several years, whereas the import price of steel structures was relatively stable. However, material cost is a market-driven and macro issue. Due to a small demand on structural steelworks in Hong Kong, customer's bargaining power is limited. Residential construction leads the building industry in Hong Kong. RC structure is almost adopted in high-rise residential buildings in the local industry, resulting in the fact that RC is more competitive and customers have better bargaining power to push down the material costs. The current construction rate of structural steelwork ranges from HK$ 20,000 per ton to HK$ 30,000 per ton in Hong Kong, which can escalate to 50,000 per ton according to specific project features. Material and fabrication costs account for 45%~50% of construction rate of structural steelworks.

The results of the case study reveal that the rate of structural steel is considerably high (i.e., HK$ 36,150 per ton). As a consequence, the cost per unit area of steel composite structure doubles that of RC structure, which makes the former one unsatisfied from the perspective of the client even though the cost of steel-framed superstructure only accounts for nearly 20% of total construction cost. The original steel composite design does not have significant benefit for improving construction program. First, the estimated construction period of steel composite structure is 1 month shorter than that of RC one. As the client states that structural steelwork takes longer time for preparation works and design approval, its overall project duration does not act as an overwhelming merit as compared with RC's. As a result, it does not contribute to a benefit of early return on investment. Other logistic issues of structural steelwork regarding crane, temporary storage, and incompatibility with E&M works further push up the overall construction cost.

These practical issues in Hong Kong are far more complicated than other regions. The local industry has severe shortages of skilled labours and land resources and lacks downstream facilities, which inevitably raise the construction cost. Given the fact that the high construction rate of structural steelwork driven by the market, the early completion of structural steelwork may offer a favourable opportunity to the development of steel construction. Although it is widely acknowledged that the erection of structural steelwork can be a fast process, it is questioned whether its overall project duration shows a similar trend. The total project duration of structural steelwork can be highly dependent on the competence of structural engineer, contractor, skilled labours and the approver. These stakeholders may not be well trained and become unfamiliar with structural steelworks because of restrictive work practices in Hong Kong. Moreover, as the client declares that the delivery time of steel materials and fabricated structures is considerable, structural steel supply chain can also influence the overall project duration.

This study presents the initial findings of structural steel supply chain and cost issues in the constructional steel industry. Given the fact of the high construction cost of structural steelwork, efforts should be made to improve construction program thereby bringing early completion of the project and early return on investment. Further studies should formulate practical strategies to develop construction program of structural steelworks.

ACKNOWLEDGEMENT

This paper forms part of the research project entitled "Marketing Strategies for the Development of the Steel Industry in Hong Kong", from which other deliverables are produced with different objectives and scope. This project is funded by the Chinese National Engineering Research Centre for Steel Construction (Hong Kong Branch). The research team wishes to acknowledge the organizations and professional interviewees who kindly participated in the data collection process and/or case studies, and provided their valuable opinions and necessary project information to facilitate this research.

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