4.1 Project and site description

Three ongoing project sites were selected in this study. These three project sites are Project A, Project B and Project C. As shown in Table 4.1, Project A and Project B adopt prefabrication method in their construction activities whereas Project C adopts conventional method in its construction activities. Those sites project are located at Klang valley area. Project A and Project C are classified under commercial building and Project B is a residential building. These projects are undertaken by XYZ Berhad, which is a construction company.

Table 4.1: Project sites, types and construction method

Site project	Type of building	Construction method
A	Commercial	prefabrication
B	Residential	prefabrication
C	Commercial	conventional

4.2 Background of XYZ Berhad

XYZ Construction Sdn. Bhd. is the core business which involves in construction services and projects in Malaysia. Since its formation, XYZ has grown in reputation and renown internationally. Its excellent track record is accredited with numerous awards such as Malaysian International Contractor of the Year Award (2000), the Malaysian Builder of the Year Award (2001) and many more.

Now, XYZ has grown to become one of Malaysian's largest construction groups in terms of projects undertaken and geographical spread. With their solid reputation in each of its specialized construction fields, XYZ is effectively become Malaysia's largest "Construction Supermarket". XYZ´s expertise in civil engineering which covers several major infrastructures works that drive the development of this country. Its expertise in civil engineering ranges from foundation work, highways, roads and bridges, airports, railways and monorails, foundation, water supply and marine work, power, oil and gas projects. Some example for projects undertaken and successfully completed includes highway, airport projects, public transportation and gas & power projects.

Apart of building construction and industrial building systems, XYZ has successfully built magnificent high-rise buildings and landmarks that dot the country's skyline.

4.3 Project A

Figure 4.1: Project A building under construction

Project A as shown in Figure 4.1 is a construction project of commercial building located at Jalan Raja Laut Kuala Lumpur (see figure 4.2). Project A is also known as Menara Bumiputra Commerce is the Head Quarters for CIMB Bank & CIMB Islamic Bank. It is a 39- storey building with a net floor of 630,000 sq. ft on site of 2.51 acres. The office space is planned on a grid of 8.8 m x 11.0 m and divided into three sections by two cores. Each section is about 6000 sq. ft. Typical office floor has a floor to floor height of 4.2 m the upper ground floor being a public area has a double volume atrium with a floor to floor height of 7.2 m. The gallery and internet banking area is enclosed at all sides by glass walls while the auditorium is fully clad in metal cladding. The building itself will also be cladded with metal cladding and curtain wall system.There are five major components composed in this building which are car park (basement 1 to level 4), Amenity (Lower ground floor), Banking Plaza (Upper Ground Floor), Banking Hall (Mezzanine, 1^{st} floor & 2^{nd} floor) and Offices (1^{st} to 19^{th} , 21^{st} to 33^{rd}). This project scope of work can be briefly described under substructure works, superstructure works, mechanical & electrical and Architectural works consisting brickworks, painting, plastering, tiling works, installation door and window frame. This project adopts prefabrication method and used PERI formwork in their construction activities. PERI is one of the prefabrication methods. The contractor will rent PERI formwork system during construction activities. There are five of PERI system component used in Project A such as climbing system, wall formwork, PERI CBC 240, PERI Vario GT 24 and PERI TRIO.

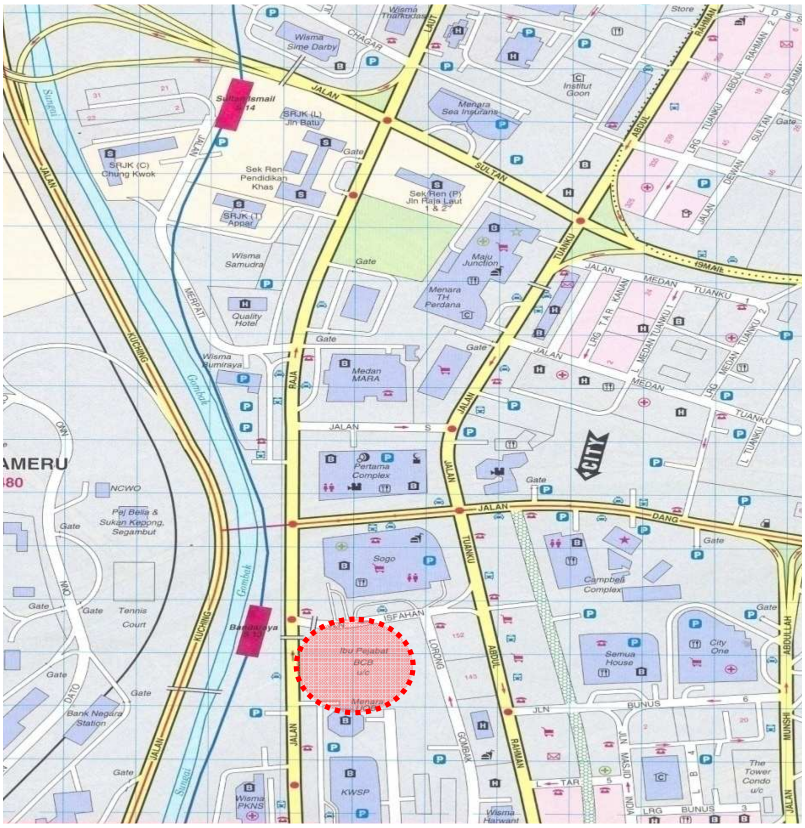

Figure 4.2: Location of Project A

4.4 Project B

Figure 4.3: Project B building under construction

Project B as shown in Figure 4.3 is a construction project of residential building located at Section 58, Persiaran KLCC Kuala Lumpur (see figure 4.4) on a site of 1.58 acres. It is develop by SDB Properties Sdn Bhd, a wholly-owned subsidiary of Selangor Dredging Berhad. Project B comprises seven number of 21-storey high rise towers arranged in radial configuration. This residential project is a condominium type with built up size ranging from 2,279sq ft. to 3,622sq ft for single-floor units, from 4,500sq ft to 5,800sq ft for duplexes and from 4,200sq ft. for the penthouses. Its facilities includes swimming and wading pools, a gym, multi-function rooms, toddlers' room and a yoga room, all located on an elevated pool deck floor. Each unit in this building will have their own private lift lobby, broadband access and Astro points. Project B building is one of the luxurious living in the heart of Kuala Lumpur City being "bungalows in the sky".

This project scope of work can be briefly described under substructure works, superstructure works, mechanical & electrical and architectural works consisting brickworks, painting, plastering, tiling works, installation door and window frame. This project adopts prefabrication method and PERI formwork in its construction activities. The contractor will rent PERI formwork system during construction activities. There are nine of PERI system componens used in Project B such as Grider wall formwork, Column Formwork, Grider Slab Formwork, Re propping, Climbing Scaffold, Vario GT 24, Multiprop GT 24, Support Frames and CBC 240

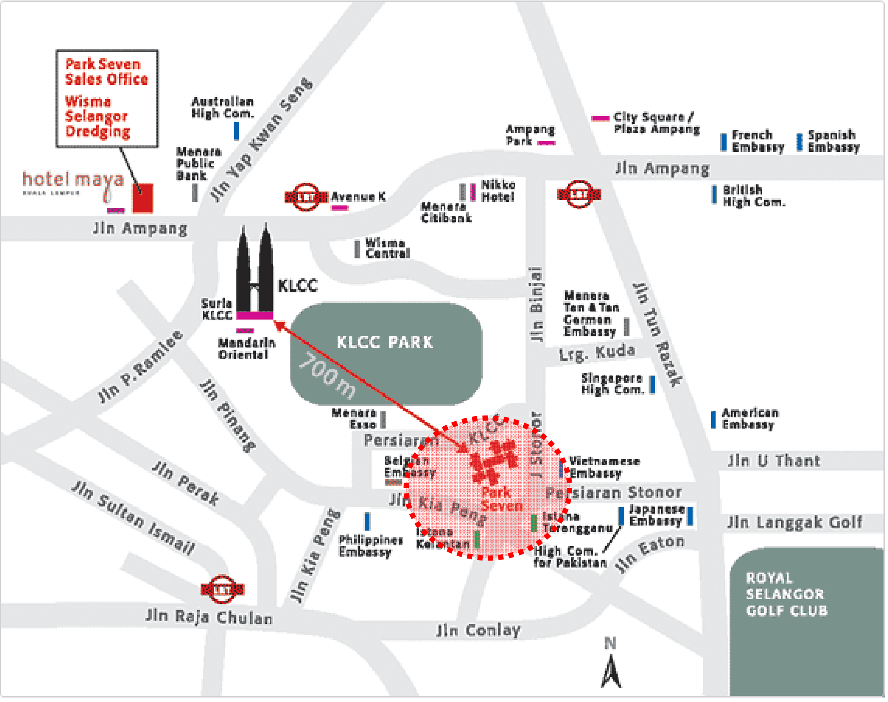

Figure 4.4: Location of Project B

4.5 Project C

Figure 4.5: Project C building under construction

Project C as shown in Figure 4.5 is a construction project of commercial building located at Lot 162, Sek – 63, Jalan Tun Razak, Kuala Lumpur (see Figure 4.6) . Project C is also formely known as La Residence. It is mixed – use development of one (1) 30 storey commercial building consists of offices, services apartments, duplex home offices, recreation/function spaces, food court, retail / commercial and car park area on site of 1.95 acre. Project C adopts conventional method which is timber as their formwork. The building is heading towards energy efficiency which incorporates:

i. The design for energy efficiency
ii. Design for water efficiency
iii. Indoor Environmental Quality and Environmental Protection

4.6 Construction waste generated from on site activities

Each site generated different amount of waste. The amount of waste was calculated using waste index calculation formula and wastage level calculation formula. As mentioned earlier in section 3.2, only selected material are chosen in this study for the calculation of wastage level namely concrete, steel reinforcement and timber. This is due to the availability of data record on site. Moreover, the materials chosen are identified as major type of construction waste generated on site with significant amount.

4.6.1 Waste index

Each site has different GFA (Gross Floor Area). GFA is the essential data in waste index calculation. GFA is the total area of all interior spaces in a structure, including occupied, common, and utility areas; the sum of the fully enclosed covered floor area and the unenclosed covered floor area of a building at all floor levels (TEFMA). Result from site interviews and data analysis concluded that, GFA for these three projects are as shown in Table 4.2. The result shows Project A has the biggest areas of GFA compared to Project B and Project C. GFA is important because it is the main factor contributing to the waste index generation on site.

Table 4.2: GFA for three project sites

Site	GFA (Gross Floor Area)
Project A	10 157.6m^2 (2.51 acre)
Project B	5 746.5m^2 (1.42 acre)
Project C	7 891.4m^2 (1.95 acre)

Waste index calculation is a very important indicator and also one of the main objectives in this study. Function of this index is to know the total amount of debris generated per GFA for each project site. Waste index calculation in this study includes data from GFA, truck volume (m^3), total number of loads for waste disposal and total number of trip for waste disposal within October 2006 until July 2007. Result of the waste index value from the project sites will be able to provide general view of total waste generated at micro and macro scale from construction industry. From the figure of waste index value, indirectly we can know all the process and activities that were conducted at construction site. Besides, we also can determine the level of awareness towards environmental aspect among workers and contractors. Based on waste generation per GFA calculation, it has been found that the waste index generation of construction waste for these projects is as shown in Table 4.3.

Table 4.3: Waste index generation on three project sites

Formula	PA	PB	PC
V = total number of loads for waste proposal	657 ; 358	189	156
N = truck volume (m^3)	4 m^3 ; 6 m^3	7.56 m^3	7.56 m^3
W = total waste generated by the project (m^3) = (V) x (N)	4776 m^3	1428.84m^3	1179.36 m^3
GFA of the project	10 157.6m^2	5 746.5m^2	7 891.4m^2
C = Waste index = W / GFA	**0.4702 m^3 / m^2 GFA**	**0.2479 m^3 / m^2 GFA**	**0.1494 m^3 / m^2 GFA**

From the table, it can be seen that Project A (which is a commercial building project which adopt prefabrication method) generates the highest value of waste index compared to Project B and Project C whereas Project C is a commercial building projects adopt conventional method generates the lowest value of waste index among these project.

If compared to Hong Kong case study, the waste index value generated for residential project is 0.175 m^3 / m^2 GFA, whereas for commercial projects is 0.200 m^3 / m^2 GFA. The waste index result from this study showed that Project A has two times higher waste index compared to commercial project in Hong Kong case study. Whereas, a study by HQ Air Force Centre for Environmental Excellence (2006) stated that the average waste generation rate for new residential building is 0.2183 m^3 /m^2 and 0.1899 m^3 /m^2 for non residential building.

4.6.2 Wastage percentage level for selected material

There are three selected materials in this study which are steel reinforcement, premixed concrete and timber. These materials are selected due to the significant amount of waste generated. Moreover their cost values are much higher than other construction materials (Table 4.4). In Malaysia construction, material price (as in Table 4.4) is verified by Construction Industry Development Board Malaysia (CIDB). CIDB is an authority which controls and monitors the price of construction material within Peninsular Malaysia, Sabah and Sarawak. Prices of building construction materials fluctuate depending on the current economic situation and market. From table 4.4, it seems that ready mix concrete and steel reinforcement are among the most expensive among the construction materials. Economically, it is important to keep an eye on concrete and steel usage during construction activities because losses and damages of these materials can increase project cost. Only, damaged steel can be sold to vendor for recycling purpose.

Table 4.4: Average price of major building materials for Peninsular Malaysia Sabah and Sarawak for August 2009.

No.	Building Materials	Unit	Peninsular Malaysia			Sabah			Sarawak		
			Lower Price	Higher Price	Average	Lower Price	Higher Price	Average	Lower Price	Higher Price	Average
			RM	RM	RM	RM	RM	RM	RM	RM	RM
1	**Ordinary Portland Cement**										
	Bag (50kg)	Bag	13.67	15.00	14.35	16.30	16.50	16.37	14.30	15.80	15.20
	Bulk	MT	266.67	290.00	277.50	-	-	-	-	-	-
2	**Reinforcement**										
	Mild Steel Bar	MT	2016.67	2150.00	2091.11	2180.00	2390.00	2281.33	2200.00	2333.33	2252.44
	High Tensile Bar	MT	2016.67	2150.00	2083.33	2200.00	2450.00	2319.81	2205.00	2325.00	2241.02
	BRC	m2	5.50	16.36	10.41	8.50	26.00	16.90	8.00	25.00	16.09
3	**Granite Aggreggate 3/4"**	MT	20.33	24.33	22.44	47.67	55.00	51.78	28.00	29.00	28.67
4	**River Sand**										
	Normal Sand	MT	7.00	25.67	13.92	30.00	35.00	32.89	27.33	29.67	28.56
	Fine Sand	MT	9.67	29.67	18.78	33.00	35.00	33.78	30.00	30.67	30.22
5	**Mining Sand**										
	Normal Sand	MT	9.00	24.33	15.81	-	-	-	-	-	-
	Fine Sand	MT	10.00	29.33	20.11	-	-	-	-	-	-
6	**Ready Mix Concrete**	m3	170.33	236.67	202.80	220.00	319.33	280.89	215.67	320.00	266.16
7	**Brick**										
	Clay Brick	piece	0.27	0.37	0.32	0.32	0.34	0.33	0.32	0.33	0.32
	Cement Sand Brick	piece	0.20	0.24	0.22	0.31	0.33	0.32	0.30	0.30	0.30

(Source: CIDB, 2009)

Timber is the main contributor to the construction waste when the construction activities adopt conventional method. Wastage level calculation in this study includes material items which are concrete, steel and timber, cumulative total material delivered at site and cumulative total work done at site. Each project site applies many type grade of concrete. However, in order to calculate the wastage level of concrete for these project sites, only major grade of concrete used in each project sites are chosen for this study. Project A uses concrete grade 40, Project B uses concrete grade 50 and Project C uses concrete grade 30. Different grade of concrete depends on the strength of the concrete. Higher grade of concrete provide higher strength of concrete quality with higher price. Whereas, lower grade of concrete give less of strength (less quality) and the price is cheaper. Result in Table 4.5 shows the calculation of wastage level for the materials in these construction projects.

Table 4.5: Wastage of material in percentage on three project sites

Project site	**Description of items**	**Total Material delivered at site**	**Total Work done at site**	**Difference**	**Wastage (%)**
A	Concrete (Cum) (Grade 40)	26623.5	26623.32	0.18	**6.7609×10^{-4}**
	Steel (Kg)	2586650	1898770	687880	**3.6228×10^{2}**
	Formwork Timber (m^2)	NIL	NIL	NIL	**NIL**
B	Concrete (Cum) (Grade 50)	15710	15298	412	**2.69**
	Steel (Kg)	2605699	2439735	165964	**6.80**
	Formwork timber (m^2)	NIL	NIL	NIL	**NIL**
C	Concrete (Cum) (Grade 30)	34286.45	32654.6	1631.85	**4.9973**
	Steel (Kg)	8238144.624	7847148.001	390996.623	**4.9826**
	Formwork Timber (m^2)	250000	238000	12000	**5.042**

The highest wastage level for steel waste is generated by Project A followed by Project B. Both Project A and Project B do not have any data on formwork timber because both projects adopt prefabrication method. As for Project C which adopts conventional method, it generates high percentage of wastage level for concrete, steel and timber which is approximately over 4%.

According to Poon (2001), allowable wastage level for concrete and steel in Hong Kong is 4%. Whereas, compared to a similar study in Thailand, average wastage level by material (in 10^3 tons) within the period 2002 to 2005 is 46% for concrete, 14% for wood waste and 1.0% for metal/steel waste. This wastage level was calculated based on different types of building in Thailand (Ghewala, 2009).

4.7 Storage and handling of material

Storage and handling of the material is one of the important aspects during construction activities. Practicing good storage can help in reducing the amount of wastage and facilitate the contractors meet allowable wastages percentages. From the observation and interview on three project sites, the applications of storage method system are almost similar for every project. Table 4.6 shows the storage material method at three project sites. The tables highlighted in pink show the same handling and storage of material for those three sites.

Table 4.6: Storage material method at three project sites

Materials	Storage Method	PA	PB	PC	Special requirements
Sand, gravel, rock, crushed concrete	Store under cover				
	Store in secure area		√		
	Store on pallets				
	Store material bound	√	√	√	
Plaster, cement	Store under cover	√	√	√	
	Store in secure area				Avoid material damp
	Store on pallets	√			
	Store material bound				
Concrete, paviors	Store under cover				
	Store in secure area				
	Store on pallets				
	Store material bound	√			
Bricks	Store under cover		√	√	
	Store in secure area				Store the material in original packaging until used
	Store on pallets	√	√	√	
	Store material bound				
Clay pipes, concrete pipes	Store under cover	√		√	
	Store in secure area		√		
	Store on pallets				
	Store material bound	√			
Wood / formwork	Store under cover		√	√	
	Store in secure area				Protect from rain
	Store on pallets				
	Store material bound	√		√	
Metals	Store under cover	√			
	Store in secure area	√	√	√	Store in original packaging until used
	Store on pallets				
	Store material bound				
Any internal fittings	Store under cover	√	√	√	Store in original packaging until used
	Store in secure area	√	√	√	
	Store on pallets				
	Store material bound				
Cladding	Store under cover		√	√	
	Store in secure area		√		The material wrapped in polythene to prevent scratches
	Store on pallets				
	Store material bound	√			

Materials	Storage Method	PA	PB	PC	Special requirements
Sheet glass,	Store under cover		√		
glazing units	Store in secure area		√		Protect glass from breakage due to the bad handling material.
	Store on pallets				
	Store material bound	√			
Paints	Store under cover		√		
	Store in secure area	√	√	√	Protect from theft
	Store on pallets				
	Store material bound				
Insulting material	Store under cover	√			
	Store in secure area	√			
	Store on pallets				
	Store material bound				
Ceramic tiles	Store under cover	√	√	√	
	Store in secure area		√		Store in original packaging until
	Store on pallets	√		√	
	Store material bound				
Glass fibre	Store under cover	√	√	√	
	Store in secure area		√		Store in original packaging until used
	Store on pallets				
	Store material bound	√			
Oils/ petrol	Store under cover		√		
	Store in secure area				Store in bowers, tanks or can ; protect from spillage
	Store on pallets				
	Store material bound	√	√	√	
Kerbstone	Store under cover				
	Store in secure area				
	Store on pallets				
	Store material bound	√			
Reinforcement	Store under cover	√			
Bar	Store in secure area		√	√	Store in original packaging until used
	Store on pallets				
	Store material bound	√			
Ironmongery	Store under cover		√		
	Store in secure area	√	√	√	Protect from theft
	Store on pallets				
	Store material bound				

Materials	Storage method	PA	PB	PC	Special requirement
Precast concrete units	Store under cover				Store in original packaging until used; away from vehicular movement
	Store in secure area		√		
	Store on pallets				
	Store material bound	√			
Clay and Slate tiles	Store under cover		√	√	Keep the material in original packaging until used
	Store in secure area		√		
	Store on pallets		√		
	Store material bound	√			

Almost all the materials at Project A are placed at open space area (Figure 4.6 and Figure 4.7) either stored in material bound or under cover since Project A has a big compound area.

Bricks is the example of material that need to be stored in original packaging until used (Figure 4.6) as well as undercover because uncovered bricks can become saturated and this will eventually result in efflorescence in the finished brickworks while timber formwork needs to be stored undercover to maintain reasonable moisture contain in timber. Whereas the others material such as cement, pipe, glass fibre are among materials only stored under cover with plastic to avoid from rain. However, some of the materials for example cement which is managed by subcontractor at Project A were not store (stand) in proper condition.

Project B has the best and effective strategic storage material system compared to Project A and Project C. Project B has limited space since the GFA of this project is the smallest compared to Project A and Project C. For that reason, this project makes use of their basement floor to place all the construction material.

Figure 4.6: Storage of brick (Store in original packaging at open space until required)

Figure 4.7: Storage of PERI formwork at open space

Hence all the materials at Project B are classified as stored in secure area and under cover (Figure 4.8 and Figure 4.9).

Figure 4.8: Storage of cement bags

Figure 4.9: Storage of tiles at secured and under cover area (keep in original packaging until used)

Some of the materials are stored in material bound (Figure 4.10). The materials stored are in good condition, neat and tidy whereas most of the materials at Project C are placed at open space area and covered with plastic because this project also has a big compound area similar to Project A.

Figure 4.10: Storage of pipe at material bound

Some of the materials need special requirements. This is caused by many factors such as cost and the composition (physical character) of the material. The high cost value material such as paint and ironmongery are always stored in secured area to protect them from theft while plaster, cement, wood, timber formwork and bricks are among of the materials need to be stored undercover or stored material bound to cover against rain.

Furthermore others material such as, internal fittings, ceramic tiles, glass fiber and clay tiles are stored in original packaging until used. The reason is to avoid these materials being damaged by on site activities such as vehicle movement.

Storage and handling of material in construction sites are monitored by subcontractor. During the visits, there are some materials which are in good condition and in proper storage, but some are not managed well. This is caused by the subcontractor's workers who did not take responsible in storing these materials. From the observation, there are few broken bags of cement on site due to the improper handling and storing process by the workers (Figure 4.11).

Figure 4.11: Improper storage of plaster

Improper storage and handling the materials will contribute to the generation of construction waste on site indirectly. Last but not least, both Figure 4.12 and Figure 4.13 show the storage method of the material to be reused.

Figure 4.12: Storage of wood to be reused

Figure 4.13: Pallet to be returned to supplier

4.8 Causes of construction waste material on Project A, Project B and Project C

Recent research indicates that about 5-10% building materials end up as construction waste on building sites (Poon et al., 2001). From the observation at three constructions sites, it can be concluded that the sources of construction waste at Project A, Project B and Project C can be classified as in Table 4.7 below. There are many factors and contributors to this figure which can be classified as human and mechanical problem. Untidy construction sites, over ordering and poor handling are the examples of human error activities that contribute to the construction waste at site whereas tower crane breakdown and the mechanism of concrete pump are the example of mechanical factors which are contribute to the generation of construction waste at site.

Table 4.7: General causes of construction waste on site

Activity on site which lead to waste construction	Types of construction waste	Reason of waste generation
Untidy construction sites	cement, packaging, steel, formwork timber	Waste materials are not segregated from useful material
Poor handling	Tile, cement, concrete, brick	Breakage, damage, losses, hacking off concrete process
Over - ordering	Steel, concrete	Error in calculation , required quantity of products unknown due to imperfect planning
Method of material packaging	Plastic packaging	Plastic packaging and cement packaging cannot be reused
Tower crane breakdown	Concrete	Concrete lift in the concrete skip turn to solid
Mechanical problem	Concrete, formwork timber	Mechanism of concrete pump ; formwork giveaway ; improper handling in jump system

Photos related to causes of construction waste at Project A, Project B and Project C are shown in Figure 4.14 until Figure 4.19.

Figure 4.14: Cement waste caused by worker attitude

Figure 4.15: Waste materials are not segregated from useful material

Figure 4.16: Cutting waste of reinforcement

Figure 4.17: Cement packaging waste

Figure 4.18: Incorrect dimension cause formwork giveaway

Figure 4.19: Jump system can cause wood waste (improper handling)

4.8.1 Main causes of concrete, steel reinforcement waste

Based on this study, it can be detailed that these are the main sources of concrete waste, steel reinforcement and formwork timber waste at three project sites waste as shown in Table 4.8. (The highlighted with pink shows the same source of steel waste for each project sites.)

Table 4.8: The main causes of concrete waste and steel reinforcement waste on three project sites

Project sites			**Activity**	**Waste material**	**causes**
PA	PB	PC			
		√	Formwork (Technical)	concrete	tower crane breakdown
√			Formwork	concrete	Hacking of concrete process
	√		Calculation	concrete	Error in calculation –extra ordering
		√	Formwork (Technical)	concrete	Concrete pump mechanism
√	√	√	Cutting	steel	Cutting error
√	√		Calculation (ordering)	steel	error in calculation – extra ordering
		√	Formwork	Timber	Life span of timber : only 2-3x can be reused

Cutting error is found to be the main causes of steel waste generated at each project sites. However, each project site generates concrete waste with different construction activities. Project A generates concrete waste during formwork activity. Project B generates steel waste from extra ordering whereas concrete waste at Project C generated from technical problem such as tower crane breakdown and the mechanism of concrete pump. Project C which adopts conventional method generates formwork timber waste from formwork activity. Formwork timber can only be used for two to three times compared to prefabrication (PERI) formwork.

4.8.2 Causes of steel reinforcement waste

It is quite difficult to control the use of steel reinforcement in building construction site because it is too cumbersome to handle due to its weight and shape. According to Poon (2001), the average wastage level for steel reinforcement is about 4%, which is normal. However from Table 4.4 the result revealed that the wastage level for steel reinforcement at Project A and Project B are fairly high which are 3.6228×10^2 % and 6.8% respectively compared to Project C which generate only 4.9826%.

There are few factors that can be pointed out as the source of steel reinforcement waste for example an unusable piece of steel reinforcement is produced when bars are cut. Additionally an excessive order of steel reinforcement resulted from the error in calculation caused by human and cutting error as well as due to the unplanned design changes was also lead to the generation of steel reinforcement waste on site.

Rounce (1998) also pointed out that the major construction waste generated on site is at the design stage and the variability in the level of design details. Even though steel is among the major waste at construction site, but most of the steel reinforcement can be reused in the next project or will be sold to vendor for recycling (Figure 4.20). Due to that, the generation of steel reinforcement waste gives less impact to the environment compared to others material such as concrete and timber.

Figure 4.20: Steel waste ready to sent back to vendor for recycling

4.8.3 Causes of concrete waste

For concrete waste, there are few causes that can be pointed out for concrete waste. Figure 4.21 show the general main causes of concrete waste on three projects site in percentage.

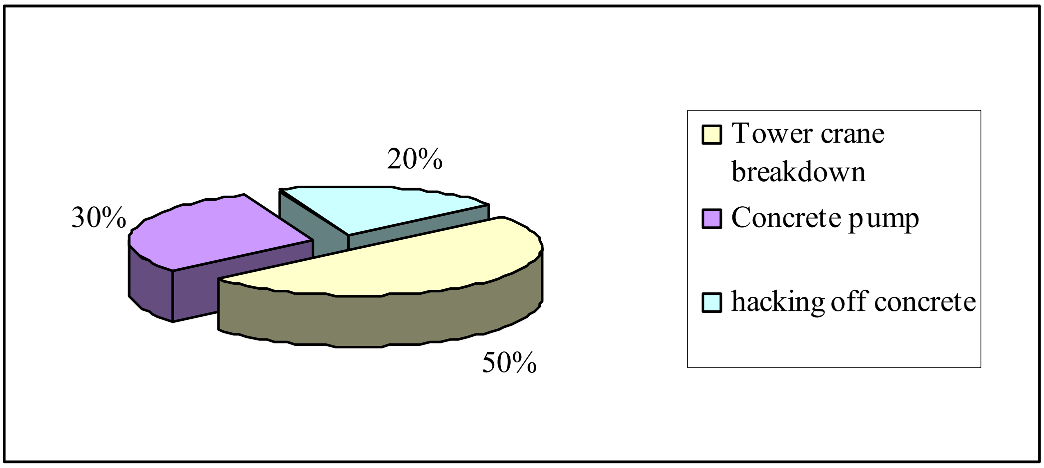

Figure 4.21: Causes of concrete waste on site

The result shows that 50% of concrete waste is caused by tower crane breakdown, 30% is from the mechanism of concrete pump and last but not least, 20% is caused by hacking off concrete process.

Tower crane (as shown in Figure 4.22) is one of the main equipment utilize in construction project. It functions to transport the construction materials. It is ideal equipment for multi-storey construction (Johnston, 1981). However it will lead to the generation of construction waste due to it breakdown, where the breakdown will directly stop the concrete pouring process and as a result, all the concrete produced cannot be used because the concrete (wet) which is lift in the concrete skip turn to solid. During the site observation, $40m^3$ concrete was disposed because of the breakdown. Interview with the site engineers, revealed that, the frequency of breakdown was about 2-3 times per month due to the age of tower crane which is over 20 years old.

Figure 4.22: Tower crane

Other than that, the mechanism of concrete pump (Figure 4.23) also leads to the generation of concrete waste. Concrete pump is a tool for transferring liquid concrete by pumping process. By using the concrete pump, the concrete will pumped to each floor. Higher level of floor will need more pressure to pump the concrete through the concrete pump. Due to the concrete pump mechanism, some of the concrete will gum against the pump column, so the amount of concrete that reached to the required that acquired area were reduced. For that reason, technically site quantity surveyors often order an additional ± 5% of concrete in order to avoid disruptions in the concrete pouring and pumping process rather than purchasing a new concrete supply where the process to purchase will take much more cost (transportation) and indirectly it will delay the duration of the construction process.

Figure 4.23: Concrete pump

Last but not least, hacking off concrete (Figure 4.24) process also can be pointed as one of the reasons for generation concrete waste. Hacking off concrete is also known as concrete repair process where extra concretes are moved to the structure edges when they flaw in the formwork assembling process. Hacking off concrete is done to provide rough, sound, clean and moist surface to the structure. This cleaning process is a manual process that uses hammer and scrapper apparatus. Generally, the waste of construction materials indirectly can increase the amount of non value adding activities such as labor and equipment for example purchasing new material, transportation system and activity of removing debris from site. Based on this study, in order to overcome this problem, a number of guidelines can be proposed in minimizing waste generation on site such as regular maintenance inspection on tower crane and improve the labor skill during formwork assembling process.

Figure 4.24: Hacking off concrete becomes waste

4.9 Construction waste handling and waste disposal

From the observation and interviews at all sites, it can be concluded that waste handling and waste disposal system are almost similar at every project sites. General waste handling and waste disposal system of the sites is shown in Figure 4.25.

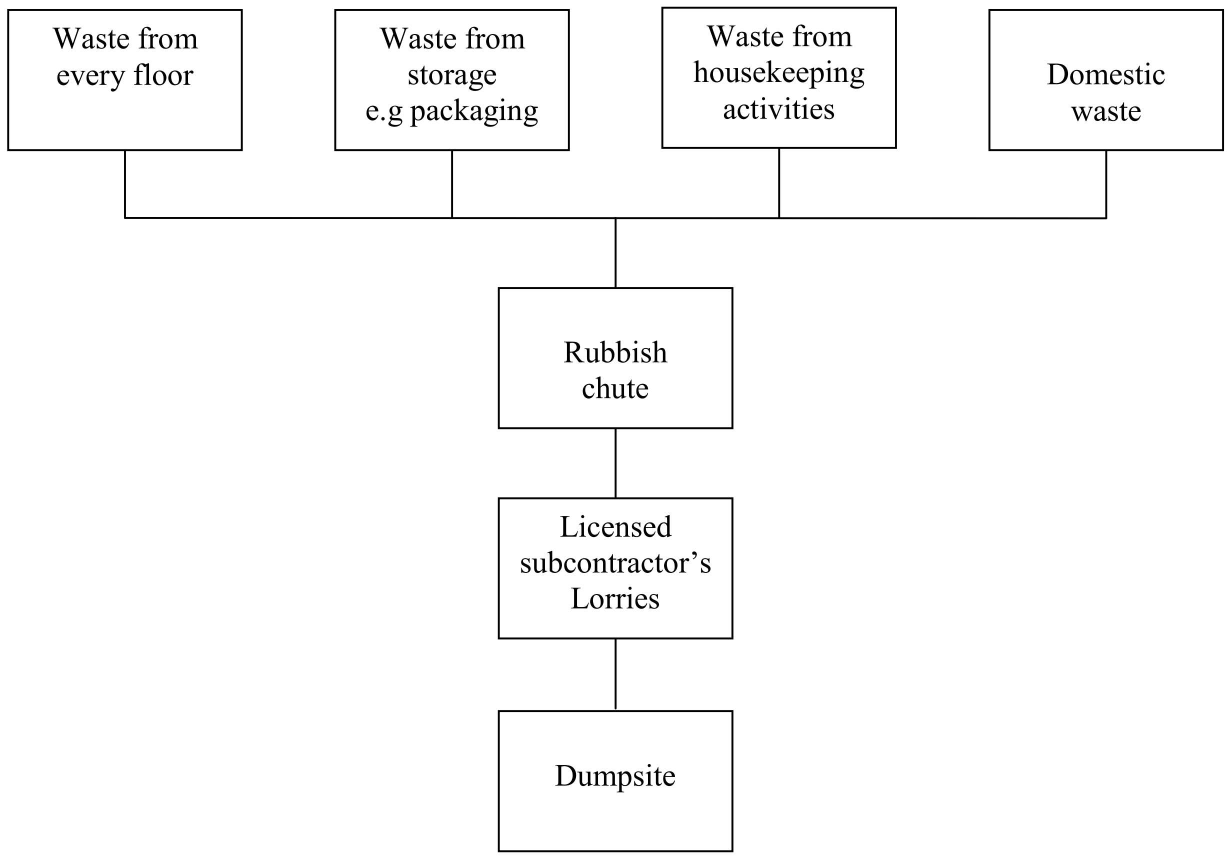

Figure 4.25: Waste handling and waste disposal general operation on site

Rubbish chute (Figure 4.26) is attached at each floor in order to dispose the construction waste of the floor. Rubbish chute is designed to facilitate construction waste disposal process become much easier as it is attached directly to a $3m^3$ bin at the ground floor.

Figure 4.26: Rubbish chute

However, interviews with site engineers found that, not all project sites attached the rubbish chute to the bin at the ground floor, some project attached the chute to the open space called dump area (Figure 4.27) and some attached with a square container that made from wood. It is depend on the projects site management itself because there is no specific operation for waste handling and waste disposal at construction site as long the waste is removed and clear from construction site. After that, the debris will be collected and disposed by the subcontractor (Figure 4.28).

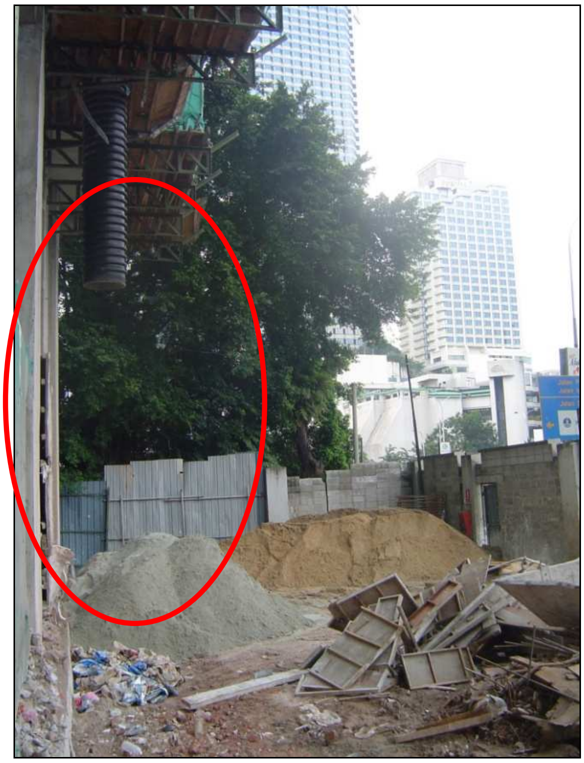

Figure 4.27: Rubbish chute attach to open space (dump area)

Figure 4.28: Construction waste (debris) ready to be disposed by subcontractor

From the site observation on this study, construction waste will be disposed through rubbish chute during the housekeeping days. Housekeeping activities normally are done once a week during weekend. During the housekeeping activities, the construction waste is gathered at one corner according the type of waste and type of material (Figure 4.29).

Figure 4.29: Wood waste are segregated; gathered at one corner

Only small material such as plastic, brick damage, small conduit and other small debris will be disposed through rubbish chute. Meanwhile, scrap material and big material such as steel reinforcement, wood, formwork are put inside $3m^3$ bin and being sent down using tower crane or fork lift. These will be disposed along with other debris. The construction waste (debris) was disposed off site by a licensed subcontractor's lorries. The subcontractor will come at the site and collect the construction waste once they received the order through the phone called from the site office.

4.10 Reused or recycle construction material

Interview conducted showed that there are some materials that can be reuse or recycle such as packaging of cement, steel reinforcement, wood formwork, pallet, telescopic shoulder bracket (Figure 4.30), air conditioner conduit (Figure 4.31) and scaffolding (Figure 4.32). Telescopic shoulder bracket and scaffolding which are still in good condition can be used at another construction project whereas air conditioner conduit will be sent back to the supplier to be recycled. There are a few brand of cements used at construction site. However there are only one packaging of cement which is SIKA brand will be recycled due to the packaging material which has high quality of packaging plastic and hard to damage (Figure 4.33). During the housekeeping activities, the workers will collect and separate the packaging. Then, the packaging will be taking back by the supplier whereas other cement packaging will be disposed along with other debris.

Figure 4.30: Telescopic shoulder bracket

Figure 4.31: Air conditioner conduit will returned to supplier for recycling

Figure 4.32: Scaffolding will be reused

Figure 4.33: Packaging of cement (SIKA) be reuse

4.11 Summary of the result

Comparison of result from Project A, Project B and Project C are shown in Table 4.9. Further explanation will be discusses later on in chapter five.

Table 4.9 Comparison of result from three project sites

Site	Project A	Project B	Project C
Type of building	Commercial building (office) -39 storey	*Residential building* - 7 blocks - 21 storey - 105 unit	*Commercial building* -30 storey
Type of Method (material use)	Prefabricated method *(PERI formworks)* Peri system use in Menara Commerce project : i. Climbing system ii. Wall formwork iii. PERI CBC 240 iv. PERI vario GT 24 v. PERI TRIO	Prefabricated method *(PERI formworks)* Peri system use in Park Seven project : i. Grider wall formwork ii. Column Formwork iii. Grider slab formwork iv. Re propping v. Climbing scaffold vi. Vario GT 24 vii. Vario GT 24 viii. Multiprop GT 24 ix. Support frames x. CBC 240	Conventional method
Phase / Activities	*October 2006 – June 2007* -Sub structure -Super structure -Architectural works -External Cladding and furnishing -M & E works	*October 2006 – June 2007* -Structural framework (starting staircase level 12 and onwards) - Architectural work -M & E works	*July 2006 – Mei 2008* Sub structure -Super structure -Architectural works -External Cladding and furnishing -M & E works
Type of waste	-Concrete	-Concrete **	-Concrete **

generated	-Rebar / steel ** -Wood -Brick -sand -Packaging of cement / cement	-rebar / steel ** -wood	-Rebar / steel ** -Wood (timber) **
Amount of waste generated	**Waste index (debris) – 0.4702 m^3 / m^2 GFA** **Wastage** Steel – 36 % Concrete - 0	**Waste index (debris) – 0.2479 m^3 m^2 GFA** **Wastage** Steel – 6.8% Concrete - 2.69%	**Waste index (debris) – 0.1494 m^3 / m^2 GFA** **Wastage** Steel – 4.9826 % Concrete - 4.9973 % Timber - 5.042 %
Recyling/reuse programme	-Packaging of cement (SIKA) sent back to supplier. -Steel -Air condition conducting -Scaffolding -Bracket		
Lifespan/duration material	Steel → 3-4 x PERI → 10-15 casting		Timber → 2- 3 x
Causes of waste	-improper handling (jump system) -improper storage -hacking -lack of the system itself -workers -error in calculation -design changes -formwork giveaway -concrete pump -sand pump -quality of material		

From Table 4.9, the result showed that Project A which is commercial building adopts prefabrication has the biggest GFA compared to Project B and Project C. Project A make used of their site compound to store all the construction material. Waste index generated at Project A is 0.4702 m^3 / m^2 GFA, which is the highest, compared to Project B and Project C. Wastage level of concrete waste and steel waste generated at Project A is 6.7609×10^{-4} and 3.6228×10^{2} respectively. Hacking of concrete process is the main source contributed to the concrete waste at Project A whereas cutting error and calculation error are among sources of steel waste at site.

Project B which is residential building adopts prefabrication has the smallest GFA compared to Project A and Project C. Project B has an effective and systematic material storage method because it makes used of the basement floor to store all the construction material. Waste index generated at Project B is 0.2479 m^3 / m^2 GFA while wastage level of concrete waste and steel waste generated at Project B is 2.69% and 6.8% respectively. Error in calculation during ordering activity for both materials concrete and steel is the main sources generation of concrete and steel waste at site.

Project C which is commercial building adopts conventional method generate the lowest less waste index compared to the others. Project A has a similar material storage method to Project A which it makes used of their site compound to store all the construction material. Wastage level of concrete waste and steel waste generated at Project C is 4.9973 % and 4.9826 % respectively. Formwork timber wastes also are one of the main construction waste materials generated at Project C as this project adopts conventional method. Tower crane and concrete pump are among sources which contributed to the concrete waste at Project C whereas cutting error is the source of steel waste at site.