Identification of Construction Waste Generated at Precast Concrete Plants: Case study

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Abstract. The government of Malaysia has introduced Industrialised Building System (IBS) or commonly termed offsite construction in other countries to replace the conventional method of construction, as one of the initiatives to overcome the problems related to waste generation and negative environmental impact in the construction industry. There are few studies of the construction waste generation focus on the offsite, particularly at precast production plant as compared to the construction site. This study aims to investigate the significant type of construction waste generated at precast concrete plants in Johor. In order to identify the type of waste generated in the process of manufacturing the precast concrete component, this study involved field observation to three precast concrete plants in Johor, together with analysing the selected organisation’s document on the waste generation and management record. Interviews were also conducted with the production manager/engineer to support the data collection process. The findings revealed that, the types of construction waste that commonly found in the precast concrete plants are concrete and steel. The most significant type of waste generated at precast concrete factory is concrete (total 1,298.56 tonnes for 3 factories, followed by 820 tonnes, 350 tonnes and 128.56 tonnes). This study provides useful information concerning waste assessment data to achieve a better understanding of construction waste in the precast concrete manufacturing industry.

1. Introduction

Malaysian construction industry is associated with a serious problem regarding the environmental sustainability that produces a large amount of construction waste quantities and negative environmental impacts [1]. In Malaysia, the rapid development of the construction industry led to a lot of waste generated due to increasing of infrastructure projects, commercial and housing buildings [1-2]. In 2016, about 35,335 tons per day of waste disposed in landfill and waste expected to be generated by Malaysian in the year 2020 is approximately 16.76 million tons [3]. Thus, the generation of construction waste is an important issue in Malaysia [4].

According to Augustine [5], construction wastes are resulting from the process of construction structures, including building structure and infrastructure projects. Construction waste can be divided into two groups namely the physical and non-physical waste [6]. The physical waste commonly
consists complete material loss which can noticeable on site and used to treat as final disposal. These waste may include timber, concrete, brick, sand, ceramic, plastic, packaging, metal, plastic and cement [6–8]. Meanwhile, the non-physical waste normally as delay time and cost overrun including in inefficiency use of equipment, mishandling materials and poor workmanship during the construction [5], [9-10].

In a study by Lu and Yuan [11] in Hong Kong, construction waste is the main source of urban waste and typically ranging from 10-30% of the total waste disposed of at landfill sites. Lai et al. [12] report that there are about 1.2-1.9 million tons per year generation of construction waste in Taiwan. Whereas, in a study by Jereme et al. [6] revealed that about 18,000 tons of wastes are generated in Malaysia per day and 75% of the wastes generated are collected and disposed to dumpsite or landfills that are not sanitary. The government of Malaysia has introduced prefabricated technology method or known as IBS to replace the conventional method of construction, as one of the initiatives to overcome the problems related to waste generation and negative environmental impact in the construction industry.

Prefabricated method enables manufacturing building components in a controlled environment and then assemble it on site which could produce better building quality and faster project completion. However, Malaysia is still lagging behind in terms of IBS adoption in the local construction industry compared to the developed countries such as Australia, United State, United Kingdom and Japan. For example in Japan, the degree of industrialization for prefabrication and construction industry has becoming advanced where the use of robotics in building construction is now adopted, whereas in Malaysia the degree of industrialization is in mechanization stage (the use of mechanized machines is common)[13].

As indicated by Azmi et al.[14], the use of IBS components for building constructions is an effective waste minimization solution for the general project and commercial project in the construction industry. The most important benefits of this system are can reduce the overall cost, time, manpower, produces better quality buildings and improve the environmental performance for overall site conditions [15-16]. However, there is still weakness in the understanding of these benefits among players in the construction sector. In the past, researchers have highlighted numerous studies the general of construction waste generated on sites, however construction waste also could be produced in a plant environment which are normally generated during manufacturing processes and the causes of waste generated is limitedly reported.

Regarding to this matter, this study seeks to identify the type of waste generated throughout the process of manufacturing of precast concrete components at the precast concrete plant and further clarify the significant types of waste generated. This study is focusing on the waste generated during manufacturing of precast concrete components at the precast concrete plant which does not include the design stage and assembly on sites.

2. Literature review
Manufacturing is different things with construction. The manufacturing described as the process is carried out in the factory by a factor of a controlled environment [16]. In contrast, construction is typically work outsides which refers to the creation of physical structures such as buildings, bridges or roadways [17]. According to Azman et al.,IBS concept is similar to Modern Method of Construction (MMC) in the UK and Off-Site Manufacturing (OSM) is used in Australia and the UK construction industry. Meanwhile, prefabrication is used both in Hong Kong and Singapore.

Precast concrete is the one of IBS which made in a factory, where a dedicated concrete batching plant; equipment that combines various ingredients to form concrete and thus to produce a specially designed concrete for building precast products such as structural beams, columns and wall systems and so on. Considering the precast elements have huge volume and heavyweights, thus the mobile
crews are required for the manufacturing process [17]. The main materials used in precast elements are concrete and steel bars [11]. In term of the type of elements, precast concrete has two main elements type namely precast reinforced concrete element and prestressed concrete element [20].

Precast reinforced concrete components commonly manufactured in the factory by using pre-assembled form and rebar or wire mesh reinforcement. After casting and curing, these components can be shipped directly to the construction site for installation. For instance, facade or parapet walls, beams, columns, slab, refuse chutes and staircases. Meanwhile, prestressed concrete commonly casting concrete into pre-assembled form in combination with rebar and strand reinforcement. The strand reinforcement would be tensioned to approximately three-quarters of their ultimate strength. Once the concrete cures to its required strength, the tensioning is released. For example, hollow core slabs, beams and planks.

It is evidenced that precast concrete manufacturing plant also could produce waste during the manufacturing process of the component. For example, in Hong Kong, Lu & Yuan [11] investigated three prefabrication plants by taking into account its upstream processes of manufacturing and transportation of precast concrete components. The findings revealed that, the waste generation rate of the precast concrete components are around 2% by weight or lower. In the UK, one of the precast concrete manufacturing plant organisations has come out with it’s own plant’s waste generation, and revealed that concrete and timber were the most significant type of waste generated at the plant (2% and 1% of waste generated, respectively)[21]. This particular organisation has successfully limited the production wastes (by disposing them to landfill) down to less than 1% of the material used. This was achieved through decreasing the demand on natural resources, efficiently reuse and recycle materials in the production chain.

Meanwhile, Wimalaya et al. [8] were conducted the surveys a few of the precast concrete production plants in Japan, the amount precast concrete production waste varies with different types of products. These types of products were classified into popular (infrastructure work), large-sized (big size and/or heavy weight product) and small-sized products (a product that can easily be carried like the one that is usually sold at a home center). Their findings were found that plants of small-sized products generated in average the highest amount of concrete wastes which was 6.07% of their total production, followed by plants of popular products with 4.45% and plants of large-sized products with only 2.96%.

3. Methodology
The methodologies adopted are discussed in this sub-topic. It includes discussion on the method of data collection process, the approach used, whereby research considerations such as the field observation, interviews and document analysis are also taken into account. Before that pilot study was done to validate the actual processes of precast concrete factory by field observation and discussion interviews with selected industry professionals. Then, the selection of case study for four precast concrete factories were carried out in order to collect actual data for this study.

3.1. Pilot Study
Before conducting a real data collection at precast concrete manufacturing plants, a pilot study was executed by visiting one precast concrete plant in Johor. This pilot study has provided a fundamental representation of the common waste generated in plant. The aim of the pilot study is to test research protocol and data collection instruments in preparation for a real study [22]. As a result, from the observations of manufacturing process at this plant, several common waste were identified such as concrete, steel and timber waste. Hence, this pilot study can assessing the feasibility of a (full-scale) study.
3.2. Selection of Case Study

According to Yin [24], there are four types of case study: single-case (holistic) designs (Type 1), single-case (embedded) designs (Type 2), multiple-case (holistic) designs (Type 3), and multiple-case (embedded) designs (Type 4). Type 4- the multiple-case (embedded) approaches have been chosen for this study in order to make a comparison of the type of waste generated between case studies and expected reasons or either similar result from the studies [23]; as cited in [24].

This study involved 3 case studies of precast concrete plants. The selected precast concrete plants are situated in Johore, Malaysia. In this paper, the author code the selected precast concrete plants as A, B and C. The selection of plants took into account the location of the companies (easy access by route transportation) and the availability of participant of interviewees in this study. The methods used in this study are field observation and interviews with production’s coordinator of precast concrete plants. Site observation and personal interview were made regarding the current production processes and situation in the plants started from material procurement, manufacturing, storage and delivery precast components process in order to identify types of construction waste and what the most of construction wastes were generated in precast concrete plants. The research tool used and the expected outcome of this study is shown in Table 1.

The participants selected for interview ware the individuals who involved directly in the precast plant and capable to provide appropriate answer and justifications to the interview questions. The details of the interviewees are shown in Table 2.

### Table 1. Research tools used and expected outcomes of the study

| Objectives                                                   | Research tools                                      | Expected outcomes                                                                 |
|--------------------------------------------------------------|-----------------------------------------------------|-----------------------------------------------------------------------------------|
| To identify the types of construction waste produced at precast concrete plant. | Field observation, interview                       | Collect information regarding common waste generated and waste management practices. |
| To determine the amount of construction waste produced at precast concrete plant. | Document analysis with record of amount production purchased and supplied, interview | Calculate and tabulate the data of total amount of waste produced. |

### Table 2. Details of the interviewees

| Precast concrete plant | Participants | Position                                      | Working experience |
|------------------------|--------------|-----------------------------------------------|--------------------|
| A                      | Interviewee 1| Quality Assurance & Control (QA&QC) Engineer  | 4 years            |
| B                      | Interviewee 2| Head of Production (Hollow core components)   | 5 years            |
| C                      | Interviewee 3| Production Engineer                           | 4 years            |

4. Results and Discussions

4.1. Precast concrete plant A

The precast plant is located in Pekan Nenas, Pontian. This company has had manufacturing division that is one of the leading manufacturers in Industrialised Building System (“IBS”), which offers a full range of precast concrete products for various projects across the Asian region. The manufacturing operation offers all types of building components such as precast reinforced concrete beams, columns,
staircases, façade walls, precast prestressed double tee slabs, and hollow core slabs. The company also manufacturing of precast concrete products for infrastructure such as bridge crossings, tunnel linings, railway sleepers and so on. A production facility was set up to produce and supply 15,000 tonnes of concrete products and applied ‘Design and Build’ option using proven integrated fast track industrialized building systems based on the precast concept for residential buildings, multi-storey carparks, commercial buildings, schools and light industrial buildings.

The processes observed at this plant are precast concrete hollow core slabs manufacturing process. The activities involved in the precast plant during field observation are:

- Receipt of concrete form batching plant
- Cleaning moulds
- Fixing of moulds or casting beds
- Fixing of rebar cages or pulling wire strands
- Concreting
- Curing
- Demoulding or cut off wire strands
- Stripping
- Drilling drainage holes
- Repair or finishing
- Storage

The type of construction waste that identified from field observations in this precast concrete plant were concrete, steel and wood. According to Interviewee 1, the main materials used for building components of precast concrete are cement, sand, aggregates, water and steels. Interviewee 1 also showed the location of construction waste were generated were found from the manufacturing process and sorted out (see Figure 1). Regarding the amount of waste generated, this plant did not possess the proper record of waste generated throughout the process. However, through interviews with interviewee 1, the most significant type of wastes produced at this plant is concrete, followed by steel and wood. Concrete wastes were generally found from concrete pouring activities and losses during the transportation and placing activities in moulds or casting beds and drilling drainage holes for hollow core slab components. The steel waste was generated during the cutting and bending activities.

When asked about the causes of the wastes generated, interviewee 1 was stated that the common causes were mainly due to labour’s mistakes and the condition of equipment/machine. Example of labour’s mistakes include improper concrete finishing and improper drilling drainage holes. However, the construction waste generated remains low at an estimated 1% as raw material quality is strictly controlled and the machine will be well maintained for production of precast concrete. The quantities of concrete waste were produced solely based on rough estimation by the selected interviewees by reason of they are reluctant to reveal the information of the organisation’s documents. The estimated production precast concrete waste quantities are tabulated in table 3.
Figure 1. (a) Concrete waste generated; (b) Steel waste

4.2. Precast concrete plant B
The precast plant is located in Ulu Choh, Pontian. The precast is specializing in precast concrete business was established in 2002. The company has permanent sheltered factories that have quality management standard to supply precast concrete components all over Malaysia and overseas. The factory’s facilities are fully mechanized and automated with a production capacity which able to produce precast products supply 6,215 tonnes per year. The production in precast concrete plant offers robust structural with faster & cleaner construction environment for Industrialised Building System (IBS) products such as precast reinforced beams, columns, staircases, precast concrete wall panels, bay windows, bathroom units, precast prestressed planks and hollow core slabs.

The processes observed at this plant are precast concrete hollow core slabs and beam components. The activities involved in the precast plant during field observation are:
- Receipt of concrete form batching plant
- Cleaning moulds
- Preparing mould/ casting bed
- Fixing reinforcement cage/ pulling wire strands
- Concreting / forming slab around the reinforcement
- Marking slab
- Curing precast concrete elements/ slabs to required length
- Demoulding
- Drilling drainage holes
- Repair
- Lifting components/ hollow core slabs to storage yard

During the field observation, it was noticed that the type of material waste that had found were concrete and steel. The participant also showed the location of construction waste were generated from the manufacturing process and sorted out (see Figure 2). Through interviews with interviewee 2, concrete wastes often occur after the manufacturing process of hollow core slabs components. However, the steel waste generated in this plant is slightly than concrete waste because most reinforcement steel is delivered to the factory on a just-in-time basis in the form of welded mesh that has been manufactured to the right dimensions. There are also several causes of waste generation identified and mentioned by him such as poor attitudes of workers and poor materials handling either in pour concrete activities or lifting components to storage yard. The quantities of concrete waste were
produced solely based on estimation by the selected organisation’s document. The estimation method used by the organisation; waste = quantity of material bought – quantity of material used. The production precast concrete waste quantities are tabulated in table 3.

![Image of concrete and steel waste](image)

**Figure 2.** (a) Hollow core concrete waste; (b) Steel waste

### 4.3. Precast concrete plant C

The precast plant is located in Seelong, Senai. There are major precast elements produced which are box culvert, precast concrete pipes, U-shape drain and tunnel precast pipe. The production of the infrastructure of the pipe is quite varied from the manufacturing process compared to building components. All pipe products are manufactured under controlled factory environment and occupy an area of about 45 hectares, has full casting facility necessary for mass production of precast components. It is demarcated into a few areas, namely the batch plant, casting and molding area, demolding and finishing area, and the storage yard. Site offices are located in proximately to the casting area. A production capacity which able to produce precast concrete products approximately 25,000 tonnes per year. The production processes were observed are tunnel precast pipe.

The processes observed at this plant are manufacturing process of tunnel precast concrete. The activities involved in the precast plant during field observation are:

- Receipt of concrete from batching plant
- Cleaning moulds
- Preparing moulds
- Fixing reinforcement cage
- Concreting
- Curing precast concrete elements
- Demoulding
- Repair
- Lifting components/ hollow core slabs to storage yard

During the field observation, it was noticed that the type of material waste that had found were concrete and steel. However, through interviews with interviewees 3, the most significant type of wastes produced at this plant is concrete, followed by steel. The interviewee was showed the location of construction waste generated from the manufacturing process and it were sorted out to the temporary area (see Figure 3). Through interviews with interviewee 3, concrete wastes were generally found causes of losses during the transportation and placing concrete activities in moulds. Meanwhile, the steel waste was generated due to the cutting and bending activities.
There are also several causes of waste generation identified and mentioned by her such as mishandling machines. For example, the component was fall during lifting to storage yard. Besides that, poor condition of machines and poor workmanship also can contribute the precast concrete had badly damage and rejected. The quantities of concrete waste were produced solely based on rough estimation by the selected interviewees. The reasons could be that either they are reluctant to reveal the information of the organisation’s documents. The production precast concrete waste quantities are tabulated in table 3.

![Figure 3. (a) Tunnel precast pipe concrete waste; (b) Steel waste](image)

5. Discussion

Concrete is the most widely used man-made construction material which can shape the built environment after water in the world [25]. However, the demand in global market for current housing, the construction industry has shifted its focus to mass production assembly and standardising product development[20]. In Malaysia, for example reports that the products of IBS precast concrete is the popular IBS component’s producer with a number of 207 plants.

Even so, these study have few studies or have not focused on the construction waste generation in offsite, particularly at precast production plant as compared to the construction site. In this study, we investigated the significant type of construction waste generated at precast concrete plants in order to identify the type of waste generated in the process of manufacturing the precast concrete component.

We found that in the construction waste for existing case studies, it was noticed that the types of construction wastes found on each of the precast concrete plants were almost similar in nature. The type of construction wastes were found is concrete and steel waste. Based on data collections, concrete waste are the highest construction waste generated in the precast concrete plants, followed by steel and wood waste. These findings extend the most type of construction waste were significant produced within manufacturing process which started from fixing reinforcement cage to lifting precast concrete components processes. In addition, the construction waste generated in the precast concrete plants still remains low as estimated 1-3% of waste. It is because of the organisations are strictly controlling materials in the precast concrete plants and the component were made in time as scheduled to deliver to the clients.

From the survey in the precast plants, it is observed that the total amount of precast concrete production was reaching a number of 294 701.44 tonnes in 2018. From the table, the biggest total amount of precast concrete wastes was produced from precast concrete plant C, representing 8,200
tonnes followed by precast concrete plant A and B which are 350 tonnes and 128.56 tonnes, respectively.

Table 3. Generation of construction wastes within precast concrete plants

| No. | Type of plant         | Amount of production (t/year) | Amount of waste (t/year) | % of waste |
|-----|-----------------------|------------------------------|--------------------------|------------|
| 1   | Precast concrete plant A | 15,000                      | 350                      | 2.33       |
| 2   | Precast concrete plant B | 6,215                       | 128.56                   | 2.06       |
| 3   | Precast concrete plant C | 25,000                      | 820                      | 3.28       |

As discussed with personal individual during field observations, the majority of interviewees stated that they have experienced concrete waste are mostly produced in precast concrete plants. As a result, the causes of construction waste were generated because of workers’ lack of awareness and poor performance of machines. However, from the view of a production manager, the manufacturing process relies on materials being delivered on a just-in-time basis and the quality and sustainability of the materials bought from supplier is also strictly supervised and controlled to avoid unnecessary waste of time, resources and, ultimately, materials.

6. Conclusion

In summary, we have presented identified type of construction waste generated that arising in manufacturing process for existing case studies. We have also shown that this is possible for causes of construction waste generated per manufacturing activities. The main kinds of waste, including concrete, steel and wood are investigated individually. We find that the construction wastes generated in Malaysian precast concrete plants are mainly caused by worker and condition of machines or equipment.

Hence, in order to minimise worker’s mistake from generation waste, the organisation’s management needs to play a role by establishing waste production checklists on material waste for each projects involved in prefabricated of precast concrete components. Thus, the sources of materials that have been used can be identified to determine the amount of waste generated and to be reviewed based on recorded data. Other than that, for the initial phase, the client must provide the specific objectives of the project by setting waste management policy to provide an effective waste management plan with the organisation’s precast concrete plants. Thus, the organisations can hire consultants who can provide guidance on waste streams and treatment options in the precast concrete plants that are appropriate to meet the needs of the client project.

Most notably, this is the first study to our knowledge to identify the type of construction waste generated throughout the process of manufacturing at the precast concrete plants and clarify the significant types of waste generated in order to provide useful information concerning waste assessment data in the precast concrete manufacturing industry. However, some limitations are worth nothing. As noted earlier, only construction waste was available in this study. Further work is needed to determine another type of waste that happens in factory such as waste of overproduction, waiting time, transportation, inventory, motion and defect product and where its exists in the factory.
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