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A Study on Recycling Waste Materials in Construction Industry

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ABSTRACT

The development of the construction industry has been greatly increasing over these decades. The high construction number produces several issues including waste. Waste materials in the construction industry have been one of the concerns due to high generation and most of them ended up in landfill. However, it is believed that these waste materials are recyclable. It is also adequate to be used in the construction industry for environmental sustainability as well as to reduce dependence on natural resources. Therefore, the primary objective of this research is to identify practices applied in the construction industry in recycling waste materials. Moreover, this study also serves the purpose to analyse the advantages and disadvantages of the common practices applied in recycling waste materials. Last but not least, it is expected as well throughout this study, that a recommendation may be made based on the effectiveness of recycling. To test the theories, an online questionnaire survey was conducted with 66 respondents from experts in the construction industry. The collected data further will be analysed using Statistical Package for Social Sciences (SPSS) version 26.0 software. From the results, the majority of the construction industry companies in Malaysia are aware of the waste management issue and practice waste materials recycling. The most recycled wastes are paper, cardboard, timber, and metal while the least recycled wastes are glass and asphalt due to their difficulties. Some of the waste categories are recycled by direct reuse methods such as timber and cardboard. Moreover, there is still room to improve the effectiveness of the current recycling system specifically in terms of operational cost. The current recycling system is beneficial in terms of resources, economic, and natural resource dependencies. Furthermore, the quality and reliability of the recycled products still need further improvement to be used as the main materials in the construction industry.

Keywords:

Recycling waste materials; Construction industry; Natural resources; Environmental sustainability; Practices of recycling waste

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1. Introduction

The increasing demand in the construction industry has led to massive progress in construction. However, the increasing construction is followed by several issues including waste. The generation of waste materials from construction is soaring; most of them are dumped in the nation's landfills. Therefore, an economically viable solution should be invented in the construction industry to control the production of waste. Moreover, it will reduce the dependence on natural resources, prolong the landfills' lifetime, and support sustainable living.

In the construction industry, the generation of waste is likely high enough and varies in size and materials. In Malaysia, the waste generation from the construction industry in year 2015 was accumulated at 10,439 tons annually [1]. There are several types of waste from the construction industry such as paper, asphalt, brick, metals, timber, plastic, glass, and concrete. Some of the wastes can be recycled with direct reuse after specific treatment while the others should go through a complex process. Moreover, it is crucial for recycled products to have characteristics close to the products made from natural resources in reason of reliability and quality.

1.1 Waste in Construction Industry

Most of the solid waste generated in the construction industry was dumped. However, they still have the potential to be recycled through the implementation of 3R (Reduce, Reuse, Recycle) to create recycled and sustainable products [2]. Most European countries have implemented the practices of recycling waste materials with the economic feasibility of 80-90% [3]. A viable method to recycle the waste will result in economic products and be able to be used in construction. Lack of implementation and improvement of waste management has been a concern as the environment is the most affected. Therefore, environmental management and awareness of sustainable development should be applied across all industries. The main goal is to minimise waste and recycle it [4].

1.2 Classification of Waste in Construction Industry

The majority of waste produced in the construction industry is non-decaying waste materials. These wastes will remain to exist for a prolonged period and may be harmful to the surroundings and environment. Therefore, the waste categorisation in the construction industry is based on materials. They are:

i. Paper and Cardboard
ii. Asphalt
iii. Bricks
iv. Metals
v. Plastic
vi. Timber
vii. Glass
viii. Concrete.

The use of paper and cardboard in the construction industry is quite large, mostly as packaging. In 2002, Hong Kong recorded more than one-third of construction waste was compromised of paper and cardboard [4] Moreover, paper and cardboard waste is categorised as major biodegradable waste which is common in municipal solid waste [4,5]. Meanwhile, the production of asphalt waste is commonly from the demolition or reconstruction activities in road works. The asphalt waste may be utilised again as long as it will preserve the main purposes of the construction [4].

Brick waste in the construction industry is commonly found during demolition activities [4]. The brick waste may contain substances from the construction such as mortar, render, or plaster. On the other hand, brick waste may be produced in small amounts as well during construction progress. The inappropriate handle of the brick is the cause as brick is categorised as brittle materials [6]. Meanwhile, metal waste produced in the construction industry may be categorised as ferrous and non-ferrous metals. The ferrous metals contain iron which steel is commonly used in the industry [7]. It is commonly used due to its stiffness which is suitable for structure. On the other hand, non-ferrous metals can be classified into Aluminium, Magnesium, and Titanium with their alloys. It is mostly used because of lightweight and more flexible than iron [6]. Most of this waste is produced in small cuts as the residue of steel works.

Plastic materials are produced with a complex process to turn them into lightweight, resilient, and resistant to corrosion material. The reliability is obtained from different polymeric compositions [8]. Plastic waste has a higher potential to pollute the water bodies and soil in the environment [9]. Most of the plastic wastes found in the construction industry are Polyethylene (PE), Polypropylene (PP), Polystyrene (PS), and Polyvinylchloride (PVC). They are mostly produced from the construction of piping, panelling, and some part of finishing works. On the other hand, timber has a vast application as well in the construction industry. The waste generation of timber is quite high as the usage is mostly for concrete formwork but some are used for wall framing. From 1999 to 2001, around 2.5 Mt of timber waste was generated annually in the UK [4].

Glass waste is mostly produced from demolition activities although careless installation may contribute to the generation of the waste as well. Glass waste has been a concern to be recycled due to the environment as the amount is piling up in the landfills and increasing demand for natural resources for glass [10]. Meanwhile, concrete is any product made by a mixture of cementitious materials that create a bond and is reactive when introduced with water [11]. The concrete commonly contains pozzolan, fly ash, additive, blast-furnace slag, or even recycled aggregates. The most basic mixture of concrete is water, cement, and both fine and coarse aggregates. The concrete waste generation in the construction industry is mostly during demolition activities [4].

1.3 Practices of Recycling Waste in Construction Industry

To minimise the amount of generated waste during construction and demolition activities, the practices of waste recycling should be applied. The recycling method is applied according to the type of waste materials. Generally, the practices of waste management can be classified into six levels according to their effectiveness [4]. The most effective practice is “Reduce” followed by “Reuse”, “Recycle”, “Compost”, and “Incinerate” while “Dumping in Landfills” is the least.

One of the most effective methods of recycling paper and cardboard waste is by turning them into new recycled paper. Nowadays, the majority of paper pulp from the industry is still made of natural resources and paper industries are accountable for 35% of logging activities [12]. The recycling of paper waste is through four main processes:

i. Pulping
ii. Screening
iii. Rolling

iv. Drying.

On the other hand, asphalt waste can be recycled by turning it into recycled aggregates which are used together with cement or bitumen for a new asphalt layer with stabiliser [4]. There are several technologies in recycling asphalt waste such as heat generation, Minnesota process, Finfalt process, etc. The most applied method is Cold In-Situ Recycling (CIR) due to some of its advantages [13].

Brick waste materials from the construction industry have the potential to be recycled as pozzolanic materials [14]. One of the methods is by turning the brick waste into fine particles for Waste Brick Blended Cement (WBBC). This process is done with homogenisation and the elimination of moisture content. The concrete mixed with WBBC is tested to have adequate quality compared to the original concrete [14]. Meanwhile, ferrous metal recycling has developed a good market as the most profitable and recyclable material although the most ideal method is direct reuse. Therefore, most ferrous metal waste will be melted to produce new steel although impurities issues may arise. However, it can be recycled totally and for a few times more with effectiveness of almost 100% [4]. On the other hand, the non-ferrous metals should be sorted prior to being recycled [4]. The extraction of non-ferrous metal from its ore involves several processes. Those steps are:

i. Calcining
ii. Roasting
iii. Smelting
iv. Converting
v. Refining whilst depending on the type of extracted metal and the purity.

The absence of iron ores is the reason for the lower grade obtained by the non-ferrous metals. Therefore, mineral beneficiation to sort the waste rock is required to maintain its economic value [15].

Plastic waste is less recycled compared to other types of waste in the construction industry. The recycling method of plastic can be mechanically, chemically, or thermally after the sorting process. The technologies utilised in sorting the plastic waste are various such as electrostatics, floatation, fluorescence, infrared, and spectroscopy [16]. Mechanical recycling is the most common method of reducing the size of plastic waste through the grinding or shredding method before further utilisation. On the other hand, chemical recycling uses chemical substances to break down the plastic composition as monomers. Thermal recycling involves heating to melt the plastic at a certain temperature before being processed as new recycled products. In the construction industry, recycled plastic waste can be used as composite, subbase, aggregates, filler, or Eco-Bricks. Most plastic waste is turned into a wood replacement in form of Wood Plastic Composite (WPC) [16]. Meanwhile, timber waste can be recycled into particleboard or Wood-Wool Cement Board. The process to form the particleboard from timber waste is done mechanically and chemically. The result of the product is adequate compared to particleboards made of natural resources [17]. For Wood-Wool Cement Board, it is used for ceiling works in construction. The timber waste is used to replace the use of natural timber and resulting in good quality for the construction industry whilst reducing timber waste [18].

Glass waste is commonly produced from demolition activities in construction. Besides the direct reuse of glass, this kind of waste can be turned into several products in recycling such as a mixture of concrete or asphalt [10]. In use for concrete or asphalt aggregates, the glass waste should be turned into Crushed Waste Glass (CWG). Meanwhile, to act as filler, the CWG size should be reduced to fine particles [10]. Moreover, glass waste can be turned into glass fibre which has vast application in the thermal layers, insulation, and ceiling [4]. On the other hand, concrete waste which is commonly found during demolition activities can be direct reuse for the subbase of pavement or as aggregate for asphalt or concrete [4]. The use of concrete waste in the size of coarse aggregate in the mixture of concrete has been applied although not vast. The mix of concrete with aggregate from concrete waste has the adequate quality and compressive strength although it is lower compared to the natural aggregates in the same ratio [19]. Therefore, the concrete waste can be used in the mix of concrete to replace the natural aggregates but at a certain portion only to ensure its quality [20].

In summary of the above, the construction industry faces significant waste generation challenges in Malaysia, prompting a surge in interest in recycling practices. Despite this, the effectiveness of recycling varies, with certain materials like paper, cardboard, timber, and metal being readily recycled, while others such as glass and asphalt pose challenges. Direct reuse methods are utilized for specific waste categories, underscoring the industry's commitment to sustainability. This study emphasizes the need for continued improvement in recycling practices, particularly in enhancing the quality and reliability of recycled products to ensure their wider adoption in construction. Moreover, the study can contribute valuable insights to government and policymakers, aiding in the enhancement of current initiatives and policies related to waste materials recycling practices within the construction industry.

2. Methodology

A questionnaire survey was conducted in this study. This study investigated the recycling of waste materials in the construction industry. SPSS Statistical software version 26.0 was used to analyse the collected data.

2.1 Define Sample

The convenience random sampling method was adapted to collect data from the target population who were conveniently available to participate in the research study. The subjects of the research were experts in the construction industry in West and East Malaysia. However, due to the COVID-19 Pandemic, the questionnaire was conducted online by sending an e-mail to the target population. In Malaysia, there were 767,563 registered workers in the Construction Industry Development Board (CIDB) which 613,843 of them were local workers and 153,720 were foreign workers [21]. Moreover, CIDB Directory listed there were 950 companies consisting of consultants, contractors, property developers, and manufacturers across Malaysia [22]. According to Survey Monkey, with a 15% of error margin and 90% of confidence rate, the targeted sample size for this research was 30 samples. In this research, the samples were chosen based on their specialities and position in the construction industry which mostly was accounted from the CIDB Directory 2020.

2.2 Distribution of Questionnaire

The questionnaire survey was conducted by sending out an e-mail to experts in the construction industry through the directory from CIDB. The survey was started on 2nd May 2022 to 30th May 2022 (4 weeks). The questionnaire was designed with fixed and same questions for all respondents which was answered through the Google Form platform.

2.3 Data Collection

Data collection was the process to collect the data from the questionnaire of the research. In this process, the respondents' demographic data was collected. Moreover, they were questioned regarding to the waste management issues such as frequency and methodology of recycling. Furthermore, it also questioned the respondents on their perceptions of current recycling system in the construction industry.

2.4 Data Analysis

Data analysis was the compilation of the collected data. It was to analyse the data and translate it in informative description. To perform the analysis, SPSS software was used. In data analysis, descriptive statistic was applied to generate the result including the summaries and graphs. To perform the analysis, the Likert scale was applied to section four of the questionnaire. The frequencies in the Likert scale were based on the range where 1= Disagree, 2= Neutral, 3= Agree, and 4= Strongly Agree. The Likert scale section was applied with Cronbach's Alpha Reliability Test as shown in Table 1. Moreover, it was analysed to obtain the mean and standard deviation. The Cronbach's Alpha Reliability Test was used to measure the reliability of the collected data [23]. The formula of Cronbach's Alpha test was as in Eq. (1).

$$\alpha = \frac{N.\bar{c}}{\bar{v}+(N-1).\bar{c}} \tag{1}$$

Table 1
Reliability Rate for The Coefficient [22]

Cronbach's alpha	Internal Consistency
$\alpha \geq 0.9$	Excellent
$0.80 > \alpha \geq 0.89$	Good
$0.70 > \alpha \geq 0.79$	Acceptable
$0.70 > \alpha \geq 0.69$	Questionable
$0.50 > \alpha \geq 0.59$	Poor
$\alpha \leq 0.59$	Unacceptable

3. Results

Descriptive statistics can be defined as a method to organise and summarise the analysed data according to its properties. The data analysis involves producing additional data such as the mean value and standard deviation which can translate the collected data for the results.

3.1 Demographic Analysis

Through this survey, the demographic data of the respondents such as gender, age range, position in the company, nature of the company, and waste recycling awareness were collected. From the data analysis, most of the respondents are male which is shown in Figure 1.

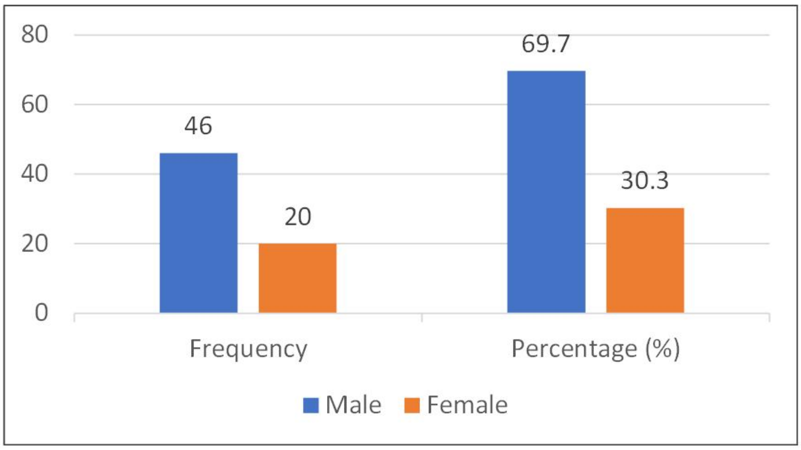

Fig. 1. Number of respondents based on gender

Moreover, the most age group of the respondents is between the ages of 26-35 as shown in Figure 2.

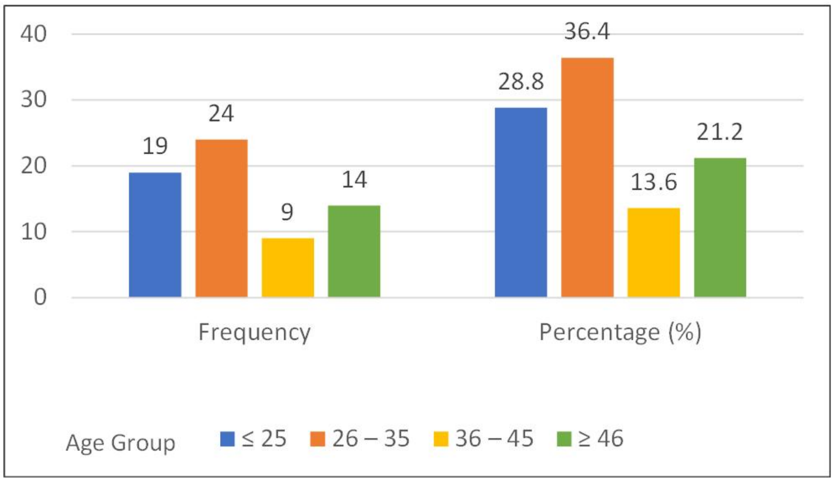

Fig. 2. Number of respondents based on age group

Engineer position is the most among the respondents as in Figure 3 and most of the respondents' company is natured in Contractor as in Figure 4.

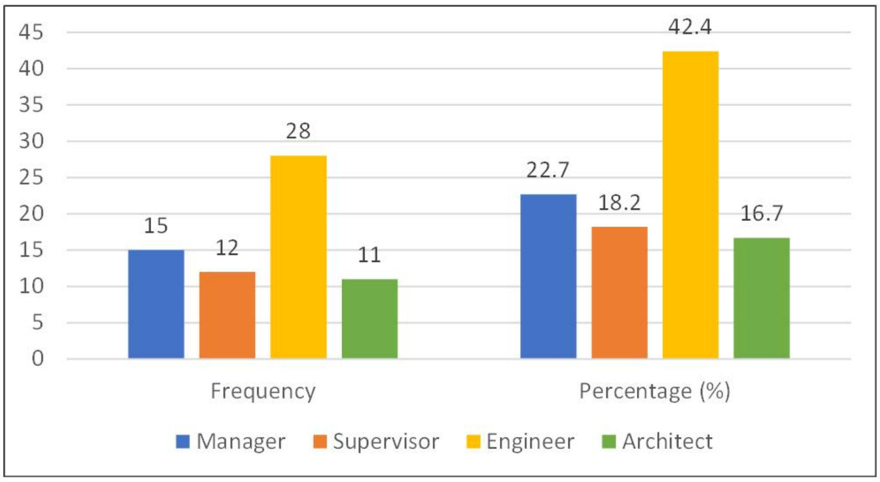

Fig. 3. Number of respondents based on position in company

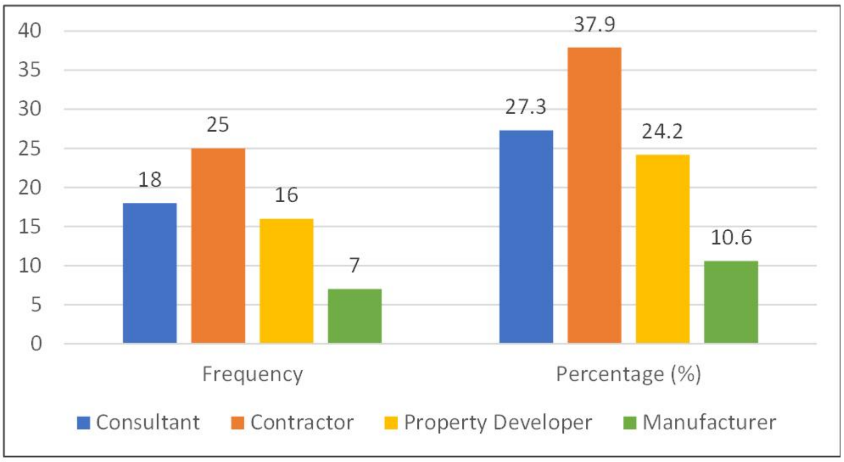

Fig. 4. Number of respondents based on nature of company

According to Table 2, the majority of the respondents answered that their companies are aware of waste materials recycling in the construction industry.

Table 2
Number of respondents based on recycling awareness

Awareness	Frequency	Percentage (%)
Yes	59	89.4
No	7	10.6
Total	66	100.0

3.2 Frequency of Waste Recycling

Table 3 shows the frequency of waste recycling done by the respondents according to the category of waste. The numbers indicate the frequency of recycling which is 1= Never, 2= Rarely, 3= Sometimes, and 4= Very Often. The recycling frequency of paper and cardboard is 82.50% which means is often done. This is due to the ease of paper and cardboard waste to be recycled within the construction site. Moreover, there is also a recommendation to reuse paper and cardboard waste for packaging [4]. Metals waste is often recycled as it can be recycled several times and has value in the market. The most profitable metals in the recycling market are ferrous metals, copper, and brass [7]. Furthermore, timber waste is often recycled as well in the construction industry. Timber waste is a renewable material with low environmental impacts. Therefore, it can be considered the most environmentally friendly in the recycling (mostly reuse) process with less or without modification [24].

Plastic waste is recycled at a moderate rate among the other categories of waste. Recycled plastic products are beneficial in terms of the environment and resource utilisation in the construction industry [25]. However, the amount of plastic waste generated in the construction industry is relatively lower than other types of waste [26]. Meanwhile, brick waste has a moderate rate of recycling as well according to Table 3. The recycling rate of brick waste is not high enough due to the high chance of contamination from demolition and lower profit in the process [26]. Moreover, out of 315 tonnes of brick waste produced, only 126 tonnes were recycled [27]. On the other hand, the conduct of concrete waste recycling is considered adequate with 61%. The process of concrete waste recycling is relatively simple as well as the utilisation of the waste is quite vast in various methods. The urgency to reduce the usage of natural aggregates in construction has been one of the main factors in switching to recycled aggregates which leads to concrete recycling [28]. Meanwhile, the portion of concrete waste recycling was reaching around three-quarters of the produced concrete waste. In 2006, it is estimated that 17,820 tonnes of concrete waste were produced and 13,365 tonnes of them were recycled [27]. Moreover, asphalt and glass waste are the least recycled due to several reasons. However, the recycling of asphalt waste is quite effective. In 1990, 50% of asphalt waste in the Netherlands was recycled into new asphalt with a composition of up to 15% [4]. On the other hand, the weak frequency of glass waste recycling is parallel with the situation where the generation of glass waste is lower. Moreover, out of 130 million tons of glass waste produced globally, only 21% are recycled. This number is quite low though that glass is an indefinite recyclable material [25]. Furthermore, glass waste is not biodegradable which will be a solid waste issue if there is no environmental-friendly and sustainable solution [29].

Table 3
Frequency of waste recycling according to category

Waste Category	1	2	3	4	Mean	Standard Deviation	Percentage (%)
Paper & Cardboard	7	4	17	38	3.30	0.99	82.50
Asphalt	22	23	15	6	2.08	0.97	52.00
Brick	12	14	33	7	2.53	0.91	63.25
Metals	6	5	22	33	3.24	0.95	81.00
Plastic	7	23	26	10	2.59	0.88	64.75
Timber	10	8	20	28	3.00	1.08	75.00
Glass	24	27	11	4	1.92	0.88	48.00
Concrete	16	14	27	9	2.44	1.01	61.00

3.3 Waste Recycling Methods

The methods to recycle the waste materials are various depending on the waste category. Table 4 shows the percentage of waste recycling method according to category. For paper and cardboard waste, the most applied recycling method is direct reuse with 62.34% of the portion. Moreover, 23.34% is accounted for recycling through the purification method. Direct reuse can be for multiple purposes such as packaging [4]. Meanwhile, the purification method is to create new recycled papers for further utilisation [12]. On the other hand, the most applied recycling method for asphalt waste is to turn it into a subbase or base (36.71%). However, 22.78% of the portion indicates the respondents do not recycle asphalt waste. This result is likely due to the process and effectiveness of recycling which is not too profitable at a small scale. The least applied method is In-Situ Recycling (12.66%). However, in-situ recycling specifically Cold In-Situ Recycling (CIR) is one of the most effective methods of recycling asphalt waste. This method can maintain the road geometry and less noise and emission in the working area [13].

The most common method applied in recycling brick waste is by crushing them into filling materials (56.25%). The replacement of limestone filler with brick waste does maintain the compressive strength of mortar although a higher amount of waste is required to create the paste [30]. Crushing brick waste into filling materials is quite effective and efficient as it can be done within the construction site. However, 16.25% of the portion belongs to Landfill Dumping which means the respondents do not recycle brick waste. In the European region, most of the brick waste is used as a replacement for natural aggregates. Moreover, brick does contain SiO2 and Al2O3 which makes a pozzolanic reaction to replace cement at a certain portion [31]. Meanwhile, metal waste recycling is considerably high in terms of frequency in the construction industry. The most applied method is the direct reuse of metal waste accounting for 51.95% of the overall portion. Meanwhile, 16.88% of the portion opted for metal waste recycling through the smelting method which is commonly applied for ferrous metals. Therefore, it can be concluded that most of the respondents are preferring direct reuse method in recycling metal waste. Moreover, in recycling metal waste, the energy used and emitted carbon footprint is up to 92% lower compared to the primary produced metal products, e.g., ferrous metals (58%), aluminium (92%), and zinc (76%) [32]. The current status of metal recycling may be referred to as Recycled Content and End-of-Life Recycling Rate (EOL-RR). The Recycled Content takes in a portion of metal production from scrap as a secondary supply while the End-of-Life Recycling Rate is more to the reuse of discarded metals to retain their functional properties [33].

Plastic waste is mostly recycled as recycled plastic products. This method accounts for 29.76% of the portion. Moreover, some respondents recycled the plastic waste into eco-bricks or Wood Plastic Composite (WPC) with 16.67% of the portion. The plastic waste also can be recycled into aggregates for asphalt although 14.29% opted for Landfill Dumping. From a perspective, this portion is still a concern as plastic waste is one of the most urgent issues in waste generation. On the other hand, the existence of plastic in the freshly cast concrete affects the workability, density, and compressive strength while it will not affect if the plastic waste is in form of fibres [25]. Moreover, plastic waste can be recycled into recycled products such as benches, decking, pipes, and even railway sleepers. Meanwhile, plastic waste such as PET, PVC, PU, LDPE, HDPE, etc. can be used with construction materials for the production of bricks, blocks, and tiles [34]. On the other hand, the most commonly applied method in recycling timber waste is direct reuse in the industry. This method is accounting for 54.32% of the overall portion. The direct reuse method in recycling timber waste is quite common, for example, the multiple uses of timber formworks in concrete casting. This method is practised not only in reducing timber waste but also in cost-saving for timber resources. Next, turning the timber waste into Particleboards is ranked second with 19.75% although 14.81% of the portion opted for “N/A”. Timber waste generated in the construction industry is dominated by formworks. The formworks which are used in concrete casting if handled properly may be reused several times for the same function [35]. The recycled timber waste can be used in structural aspects e.g., joists or beams although its function may decrease. Meanwhile, it also has functions in non-structural use such as stud work, purlins, floorboards, recycled strip flooring, parquet or block flooring, and even in furniture and landscaping uses [24]. However, treatments should be done to the timber waste to avoid decay and ensure in good condition for further purposes.

The most applied method in recycling glass waste by the respondents is crushing the glass waste to be mixed with concrete with 29.89% of the portion. This method is to replace a small portion of concrete common aggregates [10]. However, 26.44% belong to the respondents who do not recycle glass waste. Moreover, turning glass waste into filler powder obtained 12.64%. As filler powder, the glass waste can replace the Portland cement in concrete as it is a pozzolanic material [29]. Recycled glass waste can be utilised as aggregates in the concrete mixture which is applied in Auckland, New Zealand. On pavement, the glass waste can be mixed in the pavement from 20% to 100% depending on the design of vehicle loads [25]. Meanwhile, the most applied method to recycle concrete waste is by turning it into the subbase (43.53%). This method is commonly done after demolition activities where the concrete waste is abundant. Turning the concrete waste as additional aggregates for new concrete is following behind with 22.35%. This method is practised to replace a portion of up to 30% of aggregates with crushed concrete waste [4]. In the UK, the demand for aggregates for all purposes is expected 270 Mt annually where 70 Mt of this demand is occupied by the recycled concrete waste that is turned into aggregates [28]. Moreover, the utilisation of concrete waste as aggregates is proven sufficient to withstand the same load as primary aggregates for both coarse and fine aggregates [36].

Table 4
Percentage of waste recycling method according to category

Method	Paper & Cardboard	Asphalt	Brick	Metals	Plastic	Timber	Glass	Concrete
Purification	23.34	-	-	-	-	-	-	-
Asphalt Aggregates	-	22.78	-	-	13.06	-	14.94	14.12
Subbase or Base	-	36.71	-	-	-	-	-	43.53
In-Situ Recycling	-	12.66	-	-	-	-	-	-
Filling Materials	-	-	56.25	-	-	-	12.64	-
Slime Burnt Ash	-	-	12.50	-	-	-	-	-
WBBC	-	-	15.00	-	-	-	-	-
Smelting	-	-	-	16.88	-	-	-	-
Refining	-	-	-	10.39	-	-	-	-
Recycled Plastic	-	-	-	-	29.76	-	-	-
Wood Plastic Composite	-	-	-	-	16.67	-	-	-
Eco Bricks	-	-	-	-	20.24	-	-	-
Particle Boards	-	-	-	-	-	19.75	-	-
WWCB	-	-	-	-	-	9.88	-	-
Glass Fibre	-	-	-	-	-	-	5.75	-
Concrete Aggregates	-	-	-	-	-	-	29.89	22.35
Direct Reuse	62.34	-	-	51.95	-	54.32	9.20	-
Landfill Dumping	7.79	27.85	16.25	11.69	14.29	14.81	26.44	17.65
Other Recycle Methods	6.49			9.09	5.95	1.23	1.15	2.35

3.4 Satisfaction of Waste Recycling Performance

Based on Table 5, the company's recycling performance is at 76.50%. This means the respondents agree that their companies are doing well in terms of recycling waste materials in the construction industry. The performance of recycling waste materials in one's company does determine the effectiveness of the recycling rate. Ineffective construction waste management is often linked to environmental issues [26]. It also states that good waste management is important that may determine the company's performance and recycling rate. Meanwhile, the current system effectiveness is at 71.25%. This means the respondents feel that the current waste materials recycling system is good enough. A recent study based on statistical data indicates there should be more concern in the area of waste management in the construction industry [37]. Meanwhile, human resources, materials and equipment, construction method, administration, and regulation are the most factors affecting waste minimisation and management systems in the construction industry [38].

Table 5
Frequency and percentage for the satisfaction of waste recycling performance

Parameters	1	2	3	4	Mean	Standard Deviation	Percentage (%)
Company's Recycling Performance	0	13	36	17	3.06	0.68	76.50
Current System Effectiveness	2	17	36	11	2.85	0.73	71.25

3.5 Effectiveness of Waste Recycling Method

Table 6 shows the effectiveness of the waste recycling method according to the respondents. The current waste recycling method is beneficial in terms of resources with 85.25% while in terms of economics is 87.00%. Waste management including recycling and reusing in the construction industry is effective in terms of resources and costs. The implementation of effective waste management could be beneficial to the project with an estimation of up to 2.5% [27]. Moreover, the lower cost of natural resources in recycling is only 73.00% while reducing natural resource dependence is at 83.00%. In Hong Kong, a series of waste management policies involving waste disposal and recycling has been proven effective with the declining trend of waste generation annually [39]. As the recycling frequency is increasing in waste management of the construction industry, the dependence on natural resources is decreasing which will be good for the environment. The existence of recycled products has contributed to the effectiveness of the project.

Table 6
Frequency and percentage for the effectiveness of waste recycling method

Parameters	1	2	3	4	Mean	Standard Deviation	Percentage (%)
Beneficial in Resources	0	8	23	35	3.41	0.70	85.25
Beneficial in Economic	0	6	22	38	3.48	0.66	87.00
Lower Cost than Natural Resources	1	18	32	15	2.92	0.75	73.00
Reduce Natural Resources Dependence	1	10	22	33	3.32	0.79	83.00

3.6 Reliability & Quality of Recycled Products

According to Table 7, the adequate quality of recycled products is 67.00% while the reliability is 65.50%. This indicates that recycled products in the construction industry currently still have a long way to go for further development to increase their quality and reliability. Despite of, occasionally the designers do not specify the materials used in a project with recycled products. The reasons are varied from lack of durability, availability, quality, and effectiveness [40]. However, with some treatments to the waste materials, they can be turned into reliable recycled products. the Near Infrared (NIR) treatment to the recycled aggregates for concrete mixture is proven effective by reducing problematic fractions that exist previously [41]. Meanwhile, the ability of recycled products as main materials is at 68.50%. For certain portions and purposes, recycled products can be used as the main materials in the construction industry. In an experiment in concrete recycling, a concrete mixture with a 1:2¾ to 1:3 ratio of cement to concrete waste aggregate has the same compression capacity as concrete mixed with natural aggregates [19]. When the compression capacity is equal to the primary sample, it can be assumed that the recycled products have the adequate quality and reliability to be used. Moreover, plastic waste which is one of the main concerns can be turned into reliable products in form of Wood Plastic Composite (WPC) and act as the main materials. The utilisation of WPC has been applied broadly such as flooring, decking, fence, pole, etc. [16].

Table 7
Frequency and percentage for reliability and quality of recycled products

Parameters	1	2	3	4	Mean	Standard Deviation	Percentage (%)
Adequate Quality	5	19	34	8	2.68	0.79	67.00
Adequate Reliability	4	22	35	5	2.62	0.72	65.50
Able as Main Materials	3	22	30	11	2.74	0.79	68.50

3.7 Reliability Test

The purpose of the reliability test is to measure the consistency of collected data. In this research, Cronbach’s Alpha Reliability Test is used in SPSS Statistics 26.0 software. If any result of the Cronbach’s Alpha test is below 0.6, it will be considered poor and unacceptable for the research.

The highest value of the test is 1.0 which means the higher result of the test means the better the data consistency. Table 8 represents the results of the reliability test using Cronbach's Alpha. The range is between 0.738 to 0.806 with various numbers of items. Meanwhile, the overall reliability is 0.838 which is good and acceptable for the research.

Table 8
Reliability test

Parameters	Cronbach's Alpha
Satisfaction on Performance of Waste Materials Recycling	0.806
Effectiveness of Waste Materials Recycling	0.738
Reliability & Quality of Recycled Products	0.784

4. Conclusions

Waste management in the construction industry poses challenges in Malaysia. The awareness of construction waste issues is on the rise, leading to increased adoption of recycling practices. Although the current recycling system is effective in terms of resource utilization and reducing dependencies on natural resources. However, there is room for improvement, particularly in enhancing the quality and reliability of recycled products. Ensuring the compliance of recycled materials with industry standards is vital to prevent any potential failures during usage. Government involvement is critical for regulating and supporting effective waste materials recycling, especially in the construction sector.

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