Malaysian Journal Of
Civil Engineering

EVALUATION OF 3Rs CONCEPT FOR SUSTAINABLE STEEL WASTE DISPOSAL: CONTROL STRATEGY

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Article history
Received
28 August 2021
Received in revised form
15 November 2021
Accepted
01 December 2021
Published online
31 March 2022

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Graphical abstract

Abstract

The construction industry is consuming substantial quantities of raw materials in processes, and it harms the environment by producing a considerable amount of waste. Steel is one of the common wastes produced in the construction industry. This research paper analyzes steel waste disposal techniques in the construction sites in Malaysia concerning environmental perspectives and sustains steel waste efficiently. This paper aims to examine the practical disposal techniques of steel waste in construction sites using the 3Rs concept of material sustainability. A questionnaire survey was effectively distributed to evaluate the practical disposal techniques of steel waste in the construction sector. The quantitative data of 66 out of 165 respondents were analyzed using SPSS software to decide whether the results met our research objectives. The results prove that construction and demolition stages have the highest amounts percentages of steel waste. Therefore, the reuse technique is a first and preferable option for construction stakeholders rather than adopting recycling techniques which include specific processes rising CO_2 emissions. Reduce strategy: The highest impact and the top of the waste disposal hierarchy become a third option. This technique refers to the preliminary stages and stakeholders' awareness of establishing steel waste management plans. Generally, the authors concluded that conventional implementation of project activities and poor adoption of innovation except for major projects had a significant impact on construction waste and steel waste. Therefore, they suggested studying the incurred cost of adopting each technique.

Keywords: Construction industry, Disposal techniques, Steel waste, Sustainable, Control strategy

Abstrak

Industri pembinaan menggunakan sejumlah besar bahan mentah dalam proses, dan merosakkan alam sekitar dengan menghasilkan sejumlah besar sampah. Baja adalah salah satu sisa biasa yang dihasilkan dalam industri pembinaan. Kertas penyelidikan ini menganalisis teknik pelupusan sisa baja di tapak pembinaan di Malaysia yang berkaitan dengan perspektif persekitaran dan mengekalkan sisa baja dengan cekap. Makalah ini bertujuan untuk mengkaji teknik pembuangan praktikal sisa keluli di tapak pembinaan menggunakan konsep 3Rs kelestarian bahan. Borang soal selidik diedarkan dengan berkesan untuk menilai teknik pembuangan sampah besi praktikal di sektor pembinaan. Data dianalisis menggunakan perisian SPSS untuk memutuskan apakah hasilnya memenuhi objektif kajian kami. Hasilnya membuktikan bahawa peringkat pembinaan dan pembongkaran mempunyai peratusan sisa baja tertinggi. Oleh itu, teknik penggunaan semula adalah pilihan pertama dan lebih baik bagi pihak berkepentingan pembinaan daripada menggunakan teknik kitar semula yang merangkumi proses tertentu yang meningkatkan pelepasan CO2. Kurangkan strategi: Kesan tertinggi dan puncak hierarki pelupusan sampah menjadi pilihan ketiga. Teknik ini merujuk kepada peringkat awal dan kesedaran pihak berkepentingan untuk membuat rancangan pengurusan sisa keluli. Secara amnya, penulis menyimpulkan bahawa pelaksanaan aktiviti projek secara konvensional dan penerapan inovasi yang buruk kecuali untuk projek besar mempunyai kesan yang signifikan terhadap sampah pembinaan dan sampah keluli khususnya. Oleh itu, mereka mencadangkan mempelajari kos penggunaan setiap teknik.
Keywords: Industri Pembinaan, Teknik pelupusan, Sisa keluli, Lestari, Strategi kawalan

1.0 INTRODUCTION

The construction sector is an integral part of many countries' economies (Alsamarraie & Ghazali, 2021). This sector contributes to producing large amounts of unique waste materials from construction and demolition practices, leading to an unbalanced state influencing environmental issues such as CO_2 emissions (Schütte, 2015). Construction waste management is one of the most well-known barriers we experience in a construction site. Waste disposal became a problem due to the increasing numbers of construction projects, repetitive use of various building materials on-site, and land scarcity (Hatem et al., 2021).

Nowadays, steel is one of the most extensive materials usages in construction sites because of its unique characteristics and advantages compared to other materials. Although steel is considered a great sustainable material compared to other materials, steel fabrication and recycling processes make it more complicated and not easy to manage (G. Wypych, 2013). Many progressive endeavours decrease the depletion of natural resources, but achieving 100% use out of these resources is impossible; therefore, sustainability must be considered during resource planning (Akhtar & Sarmah, 2018).

The concept of waste reduction, resource reuse, and products recycling is frequently referred to as the "3Rs." Reduction entails selecting to use items carefully in order to minimize the generation of waste. Reuse refers to the recurrent use of objects or portions of items that retain useable characteristics. Recycling is the process of reusing waste as a resource. The minimization of waste could be accomplished efficiently by emphasizing the first of the three R's.

Construction wastes are still outcasted in landfills. It might be conceivable to dispose of a specific amount of construction waste through cautious planning. For instance, steel formwork may be fit for being utilized for concrete work activities, which would be reused somewhere else on the project instead of timber formwork, which is classed as waste once used. Other sorts of construction waste are equipped for being limited; For instance, items given with reduced packaging or those made out of recycled materials. There can likewise be chances to reuse materials and things in a reasonable condition (for example, doors, windows, roof tiles, and others) or change them for different materials with an alternate construction site. Materials and items that cannot be dispensed with, minimized, or reused may be discarded as waste. Wastes are arranged and classified before being sent to disposal places to enable waste contractors to oversee and guarantee that hazardous waste is handled efficiently.

The construction industry became one of the most critical sectors that influence the environment by consuming natural resources and large disposal of waste material. Moreover, it creates unbalanced ecological problems, potential sewage, and the main CO_2 emissions issue, increasing the risk of global warming by extracting materials, producing new ones, and fabrication processes. Steel is one element that makes a significant contribution to the solid waste construction industry (Yahya & Boussabaine, 2016). Steel consumed in the buildings is typically subjected to various processing technologies, such as coating, heating with non-metallic substances, reacting with chemicals, and doping with other metals. The production of steel is correlating to high levels of fuel consumption rates and subsequent CO_2 emissions.

This problem has become more extensive in recent years due to the need for more urbanization, population growth, and economic activities. This study will mainly discuss evaluating steel waste disposal techniques to create sustainable waste management processes at the construction site. Steel properties can be unchanged and recycled continuously, and thus, steel can be one of the most recycled materials on earth. Steel is the second-highest material waste generated on-site (Muhaidin & Chan, 2018). The construction industry contributes to the most influential environmental pollutants (Yahya & Boussabaine, 2010).

Different types of steel waste are disposed of on-site such as steel reinforcement bars. There are many applications of steel waste disposal practices implemented on-site. Still, it may not be the right choice for environmental issues rather than an easy way to get rid of steel waste. A hierarchy of waste management put the minimization of waste and the 3R techniques according to their priority (DOTE, 1995; Sadi & Abdullah, 2012; UNEP-IETC, 1996). The reduction is one of the most efficient methods to control and manage steel waste during the construction and demolition stages. It helps reduce waste generation, transportation, cost, disposal, and recycling (Poon et al., 2004). High concentrations of heavy metals (HMs) have adverse effects on the environment (Mertz, 1981; Vongdala, 2018). HMs include chromium (Cr), cadmium (Cd), copper (Cu), lead (Pb), nickel (Ni), and zinc (Zn) (Jaishankar et al., 2014).

The failure to handle hazardous waste, which comprises large components of toxic chemicals, heavy metals, or irradiation materials, is considered a threat to human health and the environment (Kamaruddin et al., 2017). Using inappropriate disposal practice exacerbates the problem of CO_2 emissions and increase the cost of ecological issues (Hu, 2011; Saat, 2013). Two of the best environmental advantages are the protection of landfill space and a decrease in greenhouse gases. Construction and demolition waste contributes 10-30% to the solid waste collected at many Landfills worldwide (Hu, 2011). The study aims to study the steel waste disposal techniques of the construction sites in Malaysia and evaluate the practical disposal techniques for the efficient use of steel waste. This study aims to estimate project stages that contribute to higher steel waste production and compare practical waste disposal techniques for construction sites. For the first objective, a study through construction project stages indicates higher steel waste production on site. In the second objective, a survey on the (3Rs) methods, reduce, reuse, recycling to identify the practical technique in the opinion of the stakeholders on-site. This research paper focuses only on the steel waste in construction sites due to the various types of construction waste. Recently, steel represents a significant material used in many construction sites and produces considerable waste. Focusing on steel waste allows us to assess the practices and achieve environmental sustainability. The scope of this work will cover construction sites in Malaysia. In addition, the most common types of construction projects (housing units, commercial, high residential, industrial) were taken as a sample for this research. This article discussed the gap in recent studies towards implementing construction steel waste management in the construction sector. The importance of this study is to estimate the steel waste for different stages and assess the performance of the 3R techniques in Malaysia towards waste produced on-site.

2.0 LITERATURE REVIEW

Construction waste generation occupied most researchers' interests. Many types of research focus on the quantity and the management of waste from construction practices. Thus, throughout the previous two decades, sustainable construction practices significantly impacted the construction industry — steel is among the primary sources of solid waste in the construction industry (Hu, 2011). Metals are divided into ferrous and non-ferrous, but the construction industry deals with ferrous materials in extensive use (Yahya & Boussabaine, 2016). Many steel forms are subjected to various formation and treatment processes such as coating, heating, and chemicals (Yahya & Boussabaine, 2016).

The enormous impact on the environment and high CO_2 emission of fuel consumption through fabrication processes of steel cause significant quantities of pollutants contaminating air, water and producing waste materials (Di Maria & Micale, 2014). Steel waste presented to the components will break down after some time, and residue salts are the final results of steel remaining and discharged into the dirt (Hu, 2011). These parts of steel remains will be washed by water into streams where they can take up by sea creatures and have an inconvenient effect on nature. The excessive use of raw materials, inappropriate waste handling, and lack of awareness towards the need to reduce waste are every day in construction sites in Malaysia (Begum et al., 2007). Malaysia was on The list of the major importers of steel in 2018 (Taira, 2020). Malaysia was on The list of the major importers of steel in 2018 (Taira, 2020) as shown in Table 1.

Table 1 Major importers of steel 2018

Rank	Total Imports	Mt
1	European Union (28)	44.9
2	United States	31.7
3	Germany	26.6
4	Italy	20.6
5	Thailand	15.5
6	South Korea	14.9
7	France	14.9
8	Belgium	14.8
9	China	14.4
10	Vietnam	14.1
11	Turkey	14
12	Mexico	13.1
13	Poland	12.1
14	Indonesia	11.7
15	Spain	10.8
16	Netherland	10.3
17	Canada	9.1
18	Philippines	9.1
19	India	9.0
20	Malaysia	8.0

2.1 Steel Waste

Steel is a significant component for many applications and products on the market, such as automotive, construction, and packaging. Malaysian steel consumption increased noticeably from 2000 to 2012, as shown in Figure 1. Steel has life cycle advantages over competing materials due to its relatively low energy consumption, high processability, conservation of natural resources, and widespread reuse of by-products.

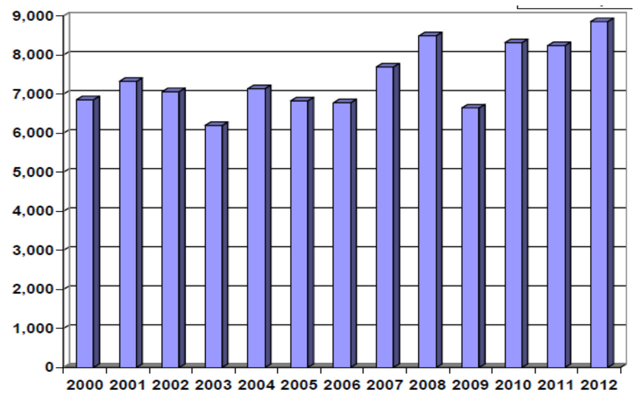

Figure 1 Steel consumption in Malaysia from 2000-2012by DOE (Hassan, 2014)

The contribution of steel to help achieve a triple lower level of environmental, economic, and social sustainability makes it vital for meeting today's needs without affecting the ability of society to meet the needs of the future. While competing materials focus their sustainability requirements on certain product application stages, the excellent steel sustainability indicators minimize the environmental impact when measured over the entire life cycle. Steel waste production is one of the pollution causes (Di Maria & Micale, 2014). The source of material waste can be found through whole construction project stages, whether in the initial stage, design stage, construction stage and covering the operation stage.

3.0 METHODOLOGY

This section will describe the research design and methodology used to achieve this research. All questions in our research questionnaire were designed to answer the research objectives (UNEP-IETC, 1996). Thus, this research technique can be accomplished through a questionnaire. Quantitative research completes three primary aspects: it conceptualizes reality as far as factors, measures these factors, and thinks about connections between these factors (Jianxin & Bingjiang, 2002).

Quantitative information collection mostly takes time and is considered time-consuming as the example measure is generally more prominent than subjective. The research design is a vital subject central to science, social science, and many different disciplines (Jianxin & Bingjiang, 2002). The research methodology received for this study is a questionnaire survey. The use of this technique accomplishes the dimensions of this research (Cohen et al., 2002). Information collected from one section is fundamental to detail and breaks down the data from the other part. One of the fundamental points of this research is to look at the steel waste management techniques utilized as a part of the construction industry. The population is groups set that achieve specification. The research population comprises contractors, sub-contractors, clients, engineers, consultants in the Johor Bahru area. The researcher has taken 40% of the targeting sample out of the population. Out of 165 sets of questionnaires, the researcher only receives 66 sets of the questionnaire from the respondents. This driven respondent sampling method in a hidden population guarantees that each person gets the same probability of taking as a sample (Cohen et al., 2002). Hence increasing the number was not the main target of this research, but selecting a considerable number with a high potential was more important. According to (Akib & Ghafar, 2015), the questionnaire was applied to collect respondents' information, attitudes, and opinions about the research event. In addition, the questionnaire used the Likert scale as an indicator instrument to the relevancy of the collected data. This questionnaire is categorized into three parts A, B, and C. For sections B and C, they have a total number of questions that reach 40 to cover all potential aspects of our research.

3.1 Section A

This section compromises the background and general information of the respondents, their job, level of education, the age of an organization, type of buildings that the organization develops, and their experience in the construction industry—the data obtained from this section is used for demography analysis.

3.2 Section B

In this section, the researcher collects the information relating to steel waste quantities produced on-site for various activities and different stages of a project to determine the percentage of steel waste and whether we need special efforts to dispose of waste.

3.3 section C

In this section, the researcher asks questions that clarify the practical steel waste disposal techniques using the Likert scale to show the extent of impact for each method. The researcher persists in identifying the suitable strategy among all these implemented in the construction site. the operational framework of this study will be as in figure 2 below:

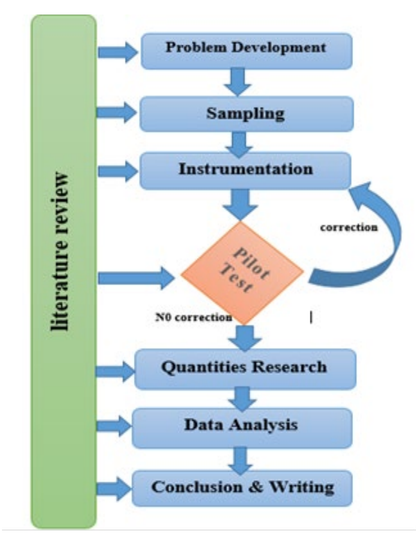

Figure 2 Operational Framework

3.4 Data Analysis

The questionnaire was analyzed taking the software of Statistical Package for Social Science (SPSS). The usage of this software calculates essential information such as frequency, percentage, and mean. The credibility and the weight of the research depend enormously on the reliability and validity of the collected data. The essential data collection refers to the first-hand data collected directly by the researcher to use for their study. Moreover, this data was obtained by directing individual examinations through respondents and review utilizing a questionnaire. The pilot test was used to discover the questionnaire's validity and reliability. It is the way to pick out whether the respondent apprehends the meaning and language of the questionnaire. It is to discover either an issue in the perception of the preparation or different questionnaire problems.

4.0 RESULTS AND DISCUSSION

In this section, the authors discussed the results and interpreted the collected data. Therefore, the authors checked the reliability and the internal consistency of the instrument used. A reliability test was conducted to show The questions' suitability to work in the questionnaire group. The value of the Alpha Cronbach test for all items illustrates that it is reliable. Alpha Cronbach's value of each section in the questionnaire should be greater than 0.7 to meet an acceptable level (Gliem & Gliem, 2003). The table shows that α= 0.89 for section 1 and 0.83 for section 2. Thus, it is a good indication that the design of questions inside the questionnaire is working as groups, and the instrument is reliable, as shown below. Thus, it is a good indication that the design of questions inside the questionnaire is working as groups, and the instrument is reliable, as indicated in Table 1 and Table 2.

Table 2 Reliability test for section 1

Reliability Statistics	
Alpha Cronbach test	N of Items
0.89	19

Table 3 Reliability test for section 2

Reliability Statistics	
Alpha Cronbach test	N of Items
0.83	21

4.1. Background of Respondents

In this part, the data was analyzed for the background of the company and the project. The first analysis would be the position of the respondents. As we can see in Figure 3 that the significant group of respondents work at the site or indirect activities on the site as shown below, 52% of the respondents work as site engineers, site supervisors, consultants, and 26% of the respondents represent property developers. It is merely their nature of work that needed them to monitor work progress on-site compared to anyone else continuously. So, that gives us practical and trusted information for this survey.

10% of the respondents work as environmental officers, and 7% and 5% refer to energy control and building control officers, respectively. We noticed that respondents in the figure give low percentages of our sample because most officers do not work at the site rather than have an audit, monitoring, or certificate-granting role.

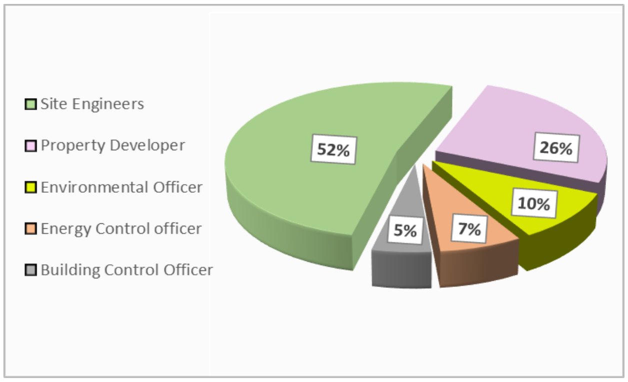

Figure 3 The Respondents Position

The results in Figure 4 show that 36% of the companies are at the age of service from 11-20 years and the same percent for the companies from 6-10 years. In less rate, we can find that the companies with years of service bigger than 20 years come in 3rd place recorded 17% of the total sample, and the new companies only represent 12%. Thus, we can conclude from all the above percentages that our survey passed on multiple experienced companies to deal with our survey questions.

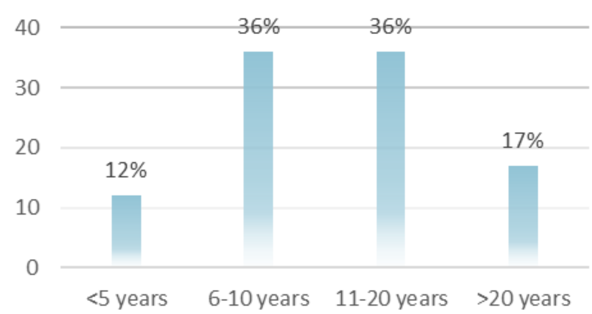

Figure 4 The Respondents Year of service

The researcher analyzed the projects that participated in this study. The analysis results shown in Figure 5 show that most respondents came from two-story building projects (housing), which contribute 71% of the total data. It is because many two-story building projects are undertaken compared to other projects. High residential projects came after the housing projects with 14%, and commercial and industrial projects last with 10% and 5%, respectively.

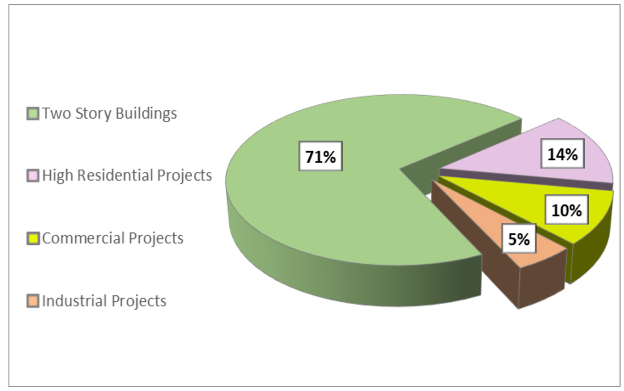

Figure 5 Type of buildings

4.2 Steel Waste Stages and Techniques Ranking

In the following analysis, the researcher analyzed the steel waste from activities in different project stages — the study results, as shown in the figure below. All the respondents agreed that the amount of steel waste produced at design, planning, and maintenance stages is recorded between (0-5) %; 95% of the respondents answered that storage and material handling do not exceed (0-5) %. However, in construction and demolition stages, the amount of steel waste record (5-10) % and (10-15) % respectively, this is a high percentage due to 64% of respondents give rising numbers of (5-10) % as compared to other options. In the demolition stage, 43% of the respondents answered that the amount of waste is between (5-10) %; while 50% of the respondents believe that the amount of waste between (10-15) % as shown in Figure 6 below:

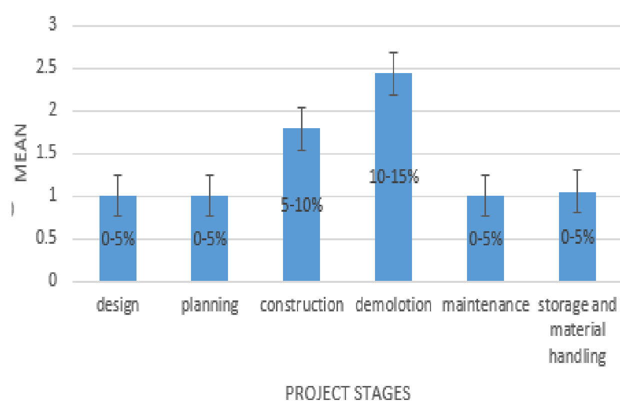

Figure 6: Steel waste amount from project stages

The data collected from the steel waste on the surveyed sites reveal a slight change in the steel waste quantities. Thus, for convenience, the data are given in percentage for project stages. However, the average amount of steel waste from all project activities records between (0-5) % from the statistical analysis. Therefore, there is a need to identify the waste produced on various stages because it represents considerable waste in the project. The practical techniques on-site analyzed, and the respondents record 21% regarding reducing technique because they believe that lowering steel waste should begin from the early stages of the project. All efforts to reduce steel waste during the construction of the building did not significantly contribute because we cannot prevent an inevitable steel waste occurrence. Also, the respondents prefer to reuse steel waste materials in different activities before they think of other techniques. It is shown that 47% of respondents agreed to use this technique as a first option before recycling the steel waste, which records 3.3 in the mean and represents 32% of respondents come as a second practical option to dispose of steel waste on-site. The results are shown in Table 4.

Table 4 Comparison of practical steel waste techniques

Techniques	N	Mean	Std. Deviation	Percent
Reduce	66	2.5476	0.30414	21%
Recycling	66	3.3492	0.54575	32%
Reuse	66	3.5476	0.55496	47%
Valid N	66			

5.0 CONCLUSION

To conclude, the first objective has been reached, representing an estimation of project stages that contribute to steel waste production and highlighting the higher steel waste stages. The researcher put in rank the techniques according to their use, the most practical method used on-site, reuse technique. Through what comes out from these results, the researcher can conclude that our local construction industry has made much effort to consume steel waste during site activities but still have some barriers that stand against full use of these materials. All endeavours to reduce steel waste during preparation, planning of the project, and site activities gave poor records. Implementing a reduction strategy is not applicable because the construction industry remains following old procedures and techniques in many parts, except for the private sector companies that rely on high technology in various work stages. Most of the addressed issues are due to insufficient actors' adherence to relevant regulations and guidelines provided by Construction Industry Development Board (CIDB). The law enforcer must strictly take the role to monitor the application of regulation on the work activities continuously.

Acknowledgment

Primarily I would thank God for being able to complete this project with success. Also, I would like to thank Dr Ali Tighnavard Balasbaneh for his valuable guidance and contribution. I would also like to thank All construction and environmental sustainability staff who inspired me and gave me ideas while working on this project.

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