Environmental Engineering and Management Journal

March 2020, Vol. 19, No.3, 439-452
http://www.eemj.icpm.tuiasi.ro/; http://www.eemj.eu

"Gheorghe Asachi" Technical University of Iasi, Romania

TURKISH ARCHITECTS' VIEWS ON CONSTRUCTION AND DEMOLITION WASTE REDUCTION IN THE DESIGN STAGE

Burcu Salgın[1]*, Nilay Coşgun[2], Cahide Aydın Ipekçi[2], Tülay Tıkansak Karadayı[2]

[1] *Department of Architecture, Faculty of Architecture, Erciyes University, Turkey*
[2] *Department of Architecture, Faculty of Architecture, Gebze Technical University, Turkey*

Abstract

Waste is one of the main environmental problems of the twenty-first century. The construction industry plays a critical role in this problem. Reducing construction and demolition (C&D) waste to a minimum is crucial considering its negative impacts on nature, human health and economies. Determining designers' awareness levels about the fact that the majority of waste generated in all life stages of buildings are largely based on design-related decisions and this waste can be reduced in accordance with these decisions is significant. With this goal, a survey was conducted with 119 architects from small to medium and large-scale projects in Turkey. The data were analysed, assessed using Microsoft Excel, correlated using the statistics program and the results were discussed. Of the participants, 52% said that they are responsible for planning and guiding the waste reduction issues in their designs. Of the designers, 66% saw waste reduction as an important component of the design stage. The designers also emphasised that providing training about waste management, improving the waste separation techniques on construction sites, and allocating specialized sections for waste management in C&D contracts are important actions. At the end of the study, a set of recommendations and suggestions were provided to deal with the C&D waste issue in Turkey. The study recommends that architects should employ all the techniques discovered in the study to minimize materials waste in their projects. This study will, therefore, contribute to materials waste minimization both in the Turkish and global construction industries.

Key words: architects' views, C&D waste, designing out waste, waste minimisation

Received: May, 2019; Revised final: August, 2019; Accepted: October, 2019; Published in final edited form: March, 2020

1. Introduction

Waste is one of the main environmental problems of the twenty-first century. Construction industry plays a critical role in this problem since waste is produced in the construction, use and disassembly/demolition of buildings for a variety of reasons. According to a study conducted in 40 countries across the world, annual construction waste production was over 3 billion tons in 2012, and is gradually increasing (Akhtar and Sarmah, 2018). The construction industry is the biggest greenhouse gas emitter in the world. It also consumes approximately one-third of water resources and produces about 40% of all waste (GBCA, 2018). Construction and demolition (C&D) waste has been comprehensively investigated since the 1970s in the global literature. C&D waste prevention and reduction have started to take place in current practices. This waste is classified as a top priority in many countries due to its large volume, amount and complexity. In 2016, 2,538 million tons of waste was generated, and construction contribution was 36.4% of the total in the European Union (Eurostat, 2019). 66.2 million tons of non-hazardous C&D waste generation was reported in the UK in 2016 (DEFRA, 2019), while 583 million tons were produced in the USA in 2014 (Townsend and Anshassi, 2017). Similarly, large amounts were also recorded for Hong Kong (EPD, 2016), China (Wang et al., 2016) and Malaysia (Taha, 2015).

C&D waste creates problem for disposal plants since they are quite bulky. Local authorities need to

* Author to whom all correspondence should be addressed: e-mail: bsalgin@gmail.com; Phone: + 90 3522076666, Fax: +90 3524376554

cope with the economic problem of collecting and disposing uncontrolled C&D waste pollution in nature (Simion et al., 2013). Additionally, Dahlbo et al. (2015) state that the joint problem was related to the lack of proper data on treated waste, the quality and quantity of outputs, and processes' technology and cost. Although C&D waste is not ordinarily classified as hazardous, it can still contain dangerous compounds. Chemical binders used to make impermeable concrete and hazardous chemicals such as paints, solvents, glues and asbestos can poison the earth and water since they come into contact with the ground when the buildings are demolished (Coşgun et al., 2009).

The prevention/reduction of C&D waste is a primary goal in the hierarchy of waste management considering natural and economic issues are taken into account. The most important responsibility belongs to architects for preventing/reducing waste in buildings' construction, use and disassembly/demolition. The literature indicates that design decisions are crucial in terms of C&D waste production during the life cycle of buildings (Bossink and Brouwers, 1996; Chandrakanthi et al., 2002; Coşgun et al., 2009; Couto et al., 2018; Ekanayake and Ofori, 2000; Faniran and Caban, 1998; Innes, 2004; Li et al., 2015; Osmani et al., 2008; Salgın, 2015).

Architects' decisions about spatial organization, design flexibility, construction methods and types of building products affect the life cycle of buildings and result in waste during their construction, use and disassembly/demolition. According to Innes (2004), one-third of C&D waste materials is caused by design errors. Moreton et al. (2016) highlighted that architects are cognizant the importance of design strategies on waste reduction. However, architects generally lack of time and knowledge to maintain waste minimization in the design stage. Additionally, Li et al. (2015) stated that designers' waste minimization behaviour can change due to economic and cultural background of the countries. Thus, determining the causes of waste production and awareness level of architects is important to increase the efficiency of designers about preventing/reducing C&D waste during the design stage.

According to Keys et al. (2000), the production of C&D waste during buildings' construction, use, disassembly and demolition is related to the complexity of the building configuration. Relevant factors also include the selection of building products during the design process, and lack of coordination and communication among design teams.

Polat and Ballard (2004) list the causes of C&D waste production by designs as:

- lack of information about the types and dimensions of products to be used,
- inaccurate information about the types and dimensions of products to be used,
- selecting types and dimensions of products without considering the production of C&D waste,
- changes in designs.

Salgın (2015) investigated the relationship between design stage and construction waste generation during the construction stage. The causes of waste generation resulting from architectural design during construction were determined to be:

- imbalances between the masses of excavated and filled areas on construction sites,
- risk of breakage and loss of features during the delivery of products from long distances to construction sites,
- lack of dimensional coordination between the building and building products,
- inaccurate quantity surveys,
- incorrect construction methods,
- on-site construction,
- lack of decisions about recycling and reuse at the building or product scale.

Salgın (2015) also examined the relationship between design stage and C&D waste generation during buildings' use stage. The causes of waste generation resulting from architectural design during building's use were determined to be:

- changes made by users due to unsatisfactory design that neglected users' needs and tastes,
- the aging of building products,
- changes of users, users' needs and tastes, the functions of buildings and legislation concerning the building industry.

When the relationship between design and waste generation during buildings' disassembly/demolition stage is examined, the inevitability of total demolition due to designs' failure to consider disassembly is found (Salgın, 2015).

The goal of this study is to assess architects' perspectives on the origins of the C&D waste that is generated by poor design, to understand current waste minimization design practices in Turkey and to investigate the barriers to C&D waste minimization.

2. Research methodology

This study conducted a survey to determine designers' awareness levels about C&D waste management. It attempted to include designers from different age groups with different workload capacities and experience from a variety of cities in Turkey. Survey questions are illustrated in the Appendix. This survey consisted of 25 questions in three sections:

- definition of C&D waste,
- causes of C&D waste production,
- the role of designers in the management of C&D waste.

The survey was sent to 200 participants. The sample was collected between November 2016 and February 2017. The participants were contacted through online survey form. 119 designers responded to the survey. Of the participants, 91 replied to all the questions, and 103 replied to the first 18 questions. The data collected using the survey were analysed and assessed using Microsoft Excel. Correlations were calculated using the statistics program (TURCOSA) and the significance level (p value) in the study was taken as 0.05. The results are presented in Results and Discussion section of this study. The findings are also presented in Figures and Tables.

3. Architectural design decisions and C&D waste prevention and reduction

The studies by Coventry and Guthrie (1998), Greenwood (2003), Poon et al. (2004) and Baldwin et al. (2009) emphasize that architects have the key responsibility to prevent and reduce waste in construction activities.

According to Coventry and Guthrie (1998), architects in the design process can reduce C&D waste in the construction, use and disassembly/demolition stages by:

- making suggestions to employers about reducing C&D waste,
- developing designs that consider C&D waste.

According to Keys et al. (2000), the prominent decisions about designs that do not produce C&D waste are:

- selecting prefabricated products,
- selecting standardized products,
- selecting products with proper dimensions and features,
- selecting recyclable products,
- designing for demount ability,
- determining products that generate waste,
- ensuring effective communication among teams.

Ballard and Zabelle (2000) reported the importance of use of the Lean Project Delivery System (LPDS) in terms of preventing/reducing losses (time, material, money, etc.) in the construction, use and disassembly/demolition stages. According to this system, data on environmental factors and requirements should first be collected, and design proposals should be generated accordingly, while iterative processes should be used to verify decisions. After making all decisions properly, lean projects should be developed. Polat and Ballard (2004) proposed the methods of Lean Design for preventing/reducing C&D waste.

Dorsthorst and Kowalczyk (2002) prescribe Integral Chain Management (ICM) as the most efficient way to benefit from materials and reduce C&D waste. ICM defines the main parameters for the use of building products as:

- Level of reuse
  - Construction
  - Construction materials
  - Construction products
- Method of reuse
  - Recycling materials
  - Down cycling materials
  - Upcycling materials
- Building stages: All actors in the construction, use, disassembly/demolition stages should plan processes with awareness and should not select products that are not suitable for recycling.

Additionally, ICM emphasizes that decisions about reuse should be made during the design stage. The main parameters of Design for Recycling, which significantly contributes to preventing/reducing C&D waste, are:

- Design for Adaptability: Flexible design that can adapt to new functions especially when the period of use and expected lifetime of buildings are different,
- Design for Dismantling: Design that either does not integrate non-recyclable products or ensures their separation before demolition,
- Design for Deconstruction: Design that allows dismantling for the reuse of products
- Application and Dismantling Techniques: Determining less harmful separation methods for the reuse of building products (Dorsthorst and Kowalczyk, 2002).

Villoria Saez et al. (2013a) completed a serial of analytical process to identify best practices which will be effective in waste reduction. The design decisions are defined as follows:

- using prefabricated or industrialized systems,
- planning the soil remains to be used in the same construction site,
- providing a space in the construction site for C&D waste management.

Gangolells et al. (2014) analysed the best C&D waste management practices for design, planning and application stages using the data collected from 74 Spanish construction companies. According to the survey results, the following criteria are considered for waste minimisation in the design stage;

- future dismantling, reuse and recycling are considered,
- reusable building elements from earlier buildings are utilized if they are technically and economically feasible,
- stakeholders' coordination is established,
- dimensional coordination of construction materials and elements are considered.

Salgın (2015) analysed the design stage in sub-stages: preparation and brief, concept design, developed design and technical design. Salgın also made continuous suggestions for each sub-stage, proposing solutions to prevent waste to be produced in the construction stage during the developed design sub-stage. The design decisions were determined to be:

- deciding which elements of the existing buildings on the construction site are to be reused,
- designing with prefabricated products,
- coordinating designs with the dimensions of products,
- selecting products with proper forms and dimensions for designs,
- selecting products in reusable condition or with recycled content,
- selecting local/regional products,
- selecting suitable application methods for

products,

- calculating excavated soil and balancing excavated and filled areas,
- deciding about using excavated vegetal earth for landscape arrangements,
- deciding about reusing probable waste on site.

Wang et al. (2015) state that architectural design which reduces waste from construction refers to design concepts. These concepts include design for;

- recycled materials,
- modular coordination,
- thin interior walls,
- hanging cradles,
- less modification.

Salgın (2015) offered suggestions to apply in the developed design sub-stage to prevent construction waste generated during buildings' use stage. The design decisions were determined to be:

- selecting durable products,
- selecting products that correspond to users' preferences and tastes,
- designing building envelopes in harmony with structural systems and with alternative solutions for interiors,
- designing with maintenance and repair options.

Salgın (2015) also offered suggestions to apply in the developed design sub-stage to prevent demolition waste generated during buildings' disassembly/demolition stage. The design decisions were determined to be:

- selecting products in reusable condition or with recycled content,
- reducing the number of products used in buildings,
- preparing a draft plan for the dismantling of buildings,
- designing with dismantling principles (spatial organization and structural systems).

The study conducted by Villoria Saez et al. (2019) highlighted the ranking of best practices in the design stage of building rehabilitation/deconstruction project. The list of best practices when designing the deconstruction and dismantling activities of a rehabilitation building is given as follows:

- providing a space for collecting and storing C&D waste,
- planning selective demolition techniques,
- designing the building to allow the recovery of the elements at the end of lifespan,
- using prefabricated or industrialized construction methods for less waste,
- using recycled, natural and/or eco-labelled materials.

According to Gálvez-Martos et al. (2018), designing in the light of modern construction methods such as pre-cast panels, steel frames, volumetric building systems enables to avoid from waste generation expected from traditional construction methods, which is supported by the study conducted by Villoria Saez et al. (2013b). It has been proved that masonry and finishing works generate more waste. To overcome the waste, specific management models which promote prevention and reduction at source are suggested (Villoria Saez et al., 2013b).

Design decisions actively determine the reduction of C&D waste throughout the entire life cycles of buildings. The size of buildings and efficiency in raw material and energy consumption play critical roles in their C&D waste generation potential. Designs with basic geometric forms and flexibility for alterations and improvements help to reduce waste during buildings' use and end-of-life stages. Additionally, selecting durable products extends buildings' service life and postpones the generation of waste. Designers sometimes consciously start the design process with the intention to prevent/reduce construction waste. Others do it due to the requirements of relevant procedures and regulations. No such enforcement occurs in Turkey. Moreover, there is also a lack of scientific studies of design approaches to increase the awareness and efficiency of designers about the causes and reduction of waste generation in the design stage.

4. Results and discussion

4.1. Definition of waste

Waste was defined as "waste generated by construction stage" by 77% of the participants, as "disassembly and demolition waste" by 75%, as "waste generated by maintenance/repair/renovation" by 51%, as "excavated soil" by 49% and as "waste generated by asphalt work" by 8%. Of the participants, 81% replied to the question about "which stage of buildings' life cycles generates the most waste" with the "disassembly and demolition stage," 46% with the "construction stage" and 27% with the "use stage". Scientific studies report that about 10% of the materials used for construction generate waste. Of total C&D waste, 30-50% is associated with renovation activities. Waste from demolition practices is estimated to constitute more than 50% of all C&D waste (Higgins, 1995).

Of the designers, 57% said that excavated soil was the largest amount of waste generated in the construction stage. Of the others, 39% said concrete, 36% said brick or clay roof tiles, 23% said metal, and 18% said wood. Although most of the designers did not perceive excavated soil as waste, they said it was the primary form of waste generated during construction stage. Fewer than 40% of the participants defined concrete and metal as waste, which is interesting and needs to be questioned, given the prevalence of reinforced concrete buildings in Turkey. Scientific studies have shown that about 40% of total C&D waste is concrete based (Oikonomou, 2005).

4.2. Causes of waste production

The analysis of the designers' opinions about the causes of waste due to the design decisions is shown in Fig. 1. "Improper building product selection" was the most common reply (32%) for "primary cause of waste". It was "lack of information/experience of architects" (35%) for "significant cause of waste," and it was "lack of modularization" for "cause of waste" (44%). The causes of waste generation due to the design stage in the categories of "primary cause of waste," "significant cause of waste," and "cause of waste" were ranked in this order:

1. Architects' lack of knowledge and experience,
2. Improper building product selection,
3. Improper details,
4. Lack of coordination and communication,
5. Insufficient design data,
6. Lack of modularization,
7. Clients' last minute requests for changes,
8. Delaying drawing revisions.

When the relation between architects' lack of knowledge-experience and improper details is examined, a weak, positive and statistically significant correlation is found (p value: 0.026). Similarly, the relation between architects' lack of knowledge-experience and improper building product selection is examined, a weak, positive and statistically significant correlation is found (p value: 0.005) (Table 1).

The opinions of the participants about the causes of waste generated during the construction stage are shown in Fig. 2. "Improper workmanship and construction" was the most common reply (44%) for "primary cause of waste". It was "improper storage areas and methods" (45%) for "significant cause of waste," and it was "unused materials and products" (39%) for "cause of waste". The causes of waste generation during construction stage in the categories of "primary cause of waste," "significant cause of waste," and "cause of waste" were ranked in this order:

1. Improper workmanship and practices,
2. Lack of knowledge and experience,
3. Improper storage areas and methods,
4. Waste caused by improper cutting and shaping during construction,
5. Delayed information about the dimensions of building products,
6. Unused materials and products,
7. Ordering excessive quantities of products,
8. Climatic conditions.

The opinions of the participants about the causes of waste generated during the use stage of buildings are shown in Fig. 3. "Lack of awareness" was the most common reply (25%) for "primary cause of waste". It was "non-durable building products" (48%) for "significant cause of waste". It was "designing without considering users' needs" (44%) for "cause of waste". The causes of waste generation during the use stage in the categories of "primary cause of waste," "significant cause of waste," and "cause of waste" were ranked in this order:

1. Non-durable building products,
2. Lack of awareness,
3. Deterioration and degradation of building products,
4. Improper details that prevent maintenance, repair and renovation,
5. Designing without considering users' needs,
6. Lack of flexibility in designs,
7. Changes in building product trends.

Table 1. The relationships between the causes of waste due to the design decisions

Variable	*n*	*mean*	*Std. Dev.*	*S. E. Mean*	*Lower Limit*	*Upper Limit*
Architects' lack of knowledge and experience	91	3.6703	0.8699	0.0912	3.4892	3.8515
Improper details	91	3.6703	0.8826	0.0925	3.4865	3.8541
Improper building product selection	91	3.9670	0.9713	0.1018	3.7648	4.1693

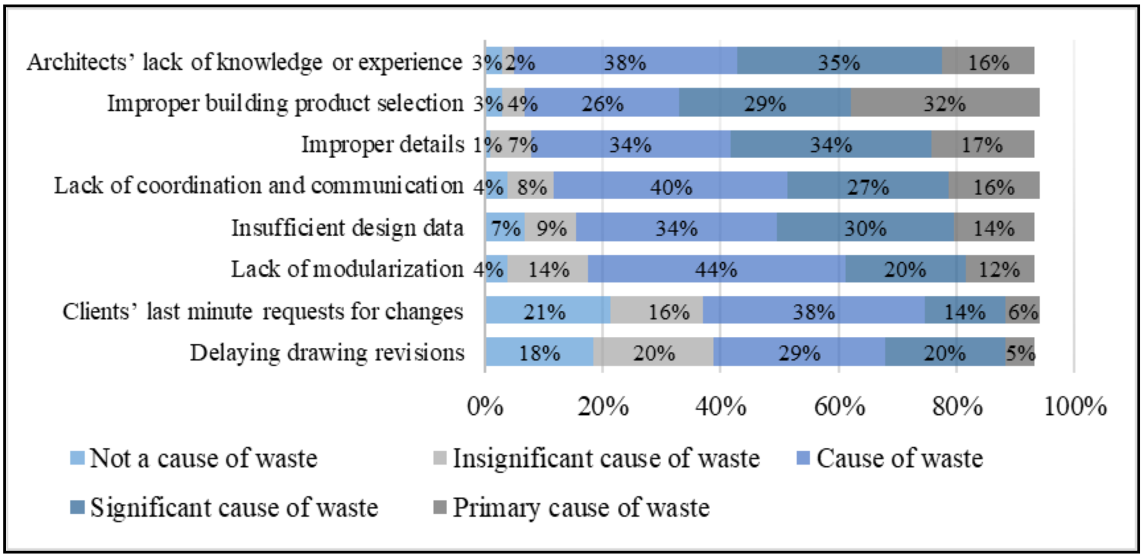

Fig. 1. Designers' opinions about the causes of waste due to design decisions

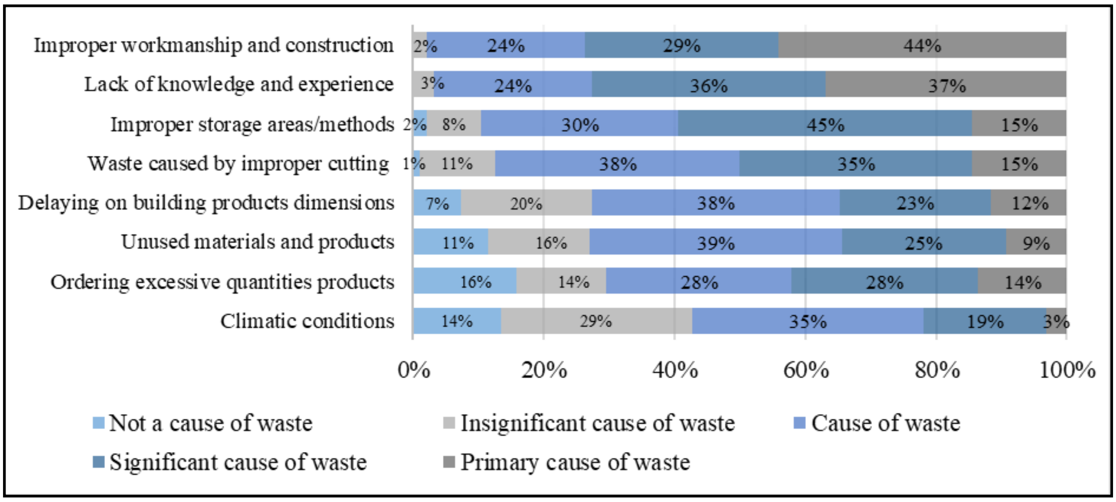

Fig. 2. Designers' opinions about the causes of construction waste

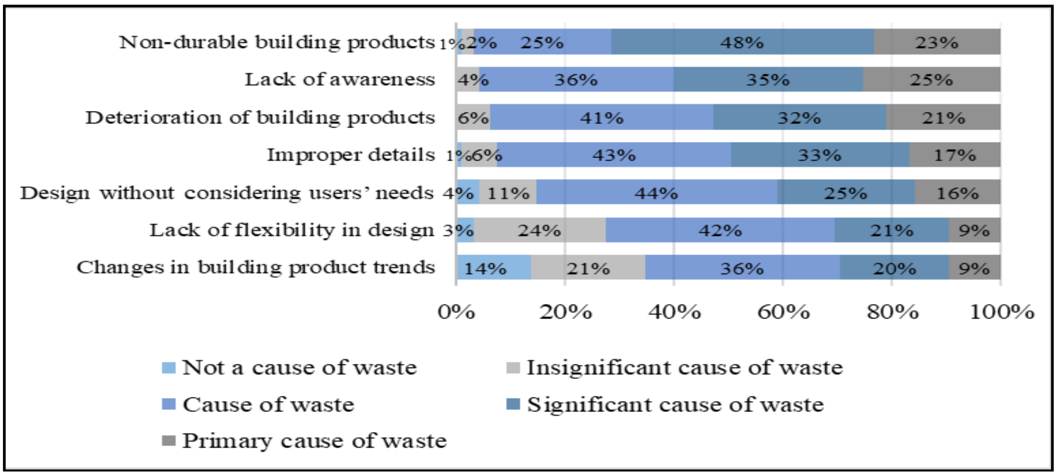

Fig. 3. Designers' opinions about the causes of waste resulting from building usage

The waste causes in use stage of the building due to lack of flexibility in designs and improper details that prevent maintenance, repair and renovation topics have been associated with the design stage. It is found that there is a weak, positive and statistically significant correlation between architects' lack of knowledge-experience and these topics (for lack of flexibility in designs, p value: <0.001; for improper details, p value: 0.042) (Table 2).

The findings about the causes of waste generated during disassembly/demolition are shown in Fig. 4. "Lack of knowledge and experience" was the most common response (26%) for "primary cause of waste". It was "lack of awareness" (39%) for "significant cause of waste," and it was "improper joints between construction products (using chemical binders instead of mechanical devices)" (44%) for "cause of waste". The causes of waste generation in buildings' disassembly/demolition stage in the categories of "primary cause of waste," "significant cause of waste," and "cause of waste" were ranked in this order:

1. Lack of knowledge and experience,
2. Lack of awareness,
3. Lack of disassembly plan for buildings,
4. Improper joints between construction products (using chemical binders instead of mechanical devices).

4.3. The role of designers in the management of C&D waste

The reactions of designers about the impacts of buildings on the deterioration of natural environment and the reduction of resources are shown in Fig. 5. Most of the designers said that they pay attention to ecological design principles and/or prefer reusable materials in their designs. Turkish and international studies have shown the critical role of designers in the reduction of C&D waste.

The opinions of designers about this critical role are identified in this study. Among the participants, 76% thought that selecting recyclable materials is their most important responsibility. Additionally, 66% of participants drew attention to the significance of sensitivity about reducing C&D waste during the design stage, and 53% said that developing designs using advanced and prefabricated construction systems is important.

Table 2. The relationships between the causes of waste in use stage and architects' lack of knowledge and experience

Variable	*n*	*mean*	*Std. Dev.*	*S. E. Mean*	*Lower Limit*	*Upper Limit*
Architects' lack of knowledge and experience	91	3.6703	0.8699	0.0912	3.4892	3.8515
Lack of flexibility in designs	91	3.1099	0.9826	0.1030	2.9052	3.3145
Improper details that prevent maintenance, repair and renovation	91	3.6154	0.8663	0.0908	3.4350	3.7958

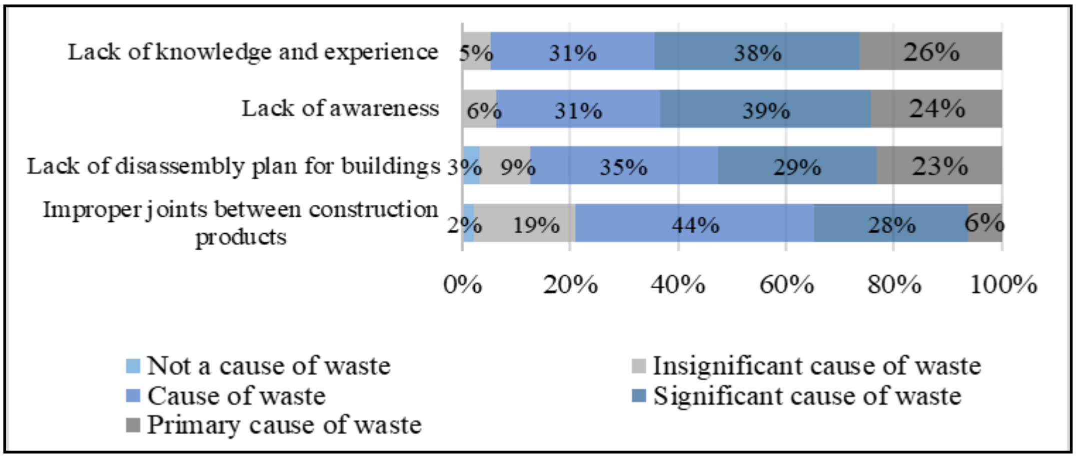

Fig. 4. Designers' opinions about the causes of waste at the disassembly/demolition stage

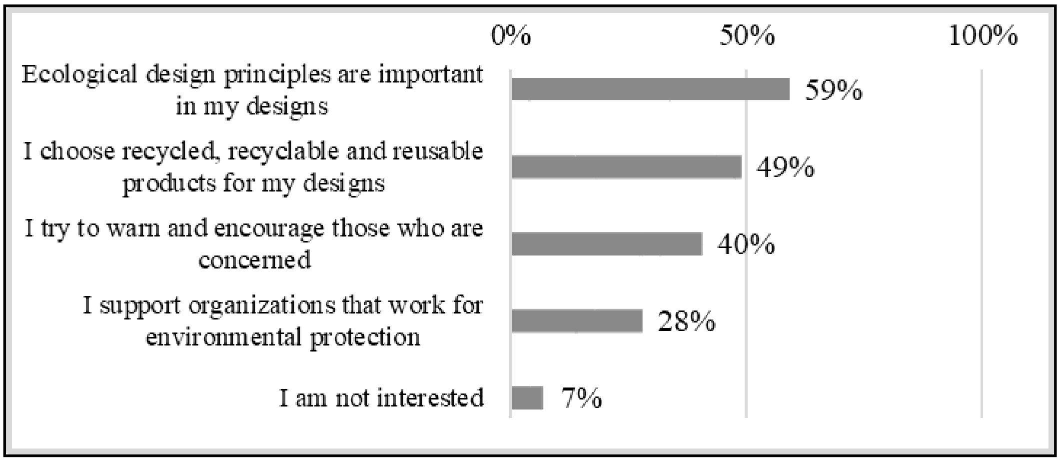

Fig. 5. Designers' reaction to the deterioration and reduction of resources

Of the participants, 46% said that giving recommendations to clients and insisting on recyclable materials is a critical task. 45% of participants drew attention to select recycled materials and 12% of them drew attention to select second-hand products. Other designer tasks included: active project management, encouraging green and energy efficient buildings with legislation, awareness about recycling, more sensitive and effective ways to recover and dispose of excavated soil. The findings indicate that the designers who responded to the survey had high levels of awareness about their critical role in the reduction of C&D waste.

The participants were asked whether they consider preventing, reducing and disposing of C&D waste during the construction, use and disassembly/demolition stages of buildings. The findings are shown in Fig. 6. Most of the participants said "yes" or "partly" when asked if they consider preventing, reducing and disposing of C&D waste during the construction, use and disassembly/demolition stages of buildings in the design stage. On the other hand, the percentage of respondents who expressed their concern about the disassembly and demolition stage in the design stage was less than 50%. Although 81% of the participants identified the disassembly and demolition stage as the stage that generates the most waste, they still do not consider it during the design stage, which is a logically incompatible result.

Of the participants, 14 said that they take preventing and reducing waste into account in the design stage, while its disposal remains secondary. These participants prioritize the functionality and durability of designs. They also mentioned that they give recommendations to employers, but this was generally ignored. They emphasize the importance of reusing excavated soil in filling activities of another construction site. One contributor working in an LEED consultancy company reported that they prepare waste management plans. Another participant reported becoming aware about the subject only after graduation. The respondents also said that it is almost impossible to reduce or prevent waste in the case of demolishing entire buildings, while care can be taken in partial demolitions. They also said that they choose recyclable materials.

According to the designers about choosing recyclable, recycled and second hand building products in their designs, the designers choose or can choose recyclable (89%) and recycled products (%99), but do not choose second hand products (65%). If a second hand and/or recycled product market developed in Turkey, the designers would still prefer recycled products (89%) over second hand products (1%).

Some respondents reported that they helped to raise clients' awareness and received positive feedback because using recyclable building products is nature friendly. On the other hand, others said that they are reluctant to use recycled products, they may choose them for the infrequently used parts of buildings, and they can feel free to use or suggest them only after they are well informed about their properties. The respondents who expressed negative opinions about recycled or second hand construction products said that user preferences are of utmost importance, and the reliability, quality and durability of these products make it impossible to use them in Turkey. The lack of second hand building product activities at the business and corporate scales in Turkey also supports this claim.

While the second hand product selection is one of the critical roles of the architect in C&D waste reduction, the relation between whether or not they prefer second hand products in their design is examined. There is a weak, negative and statistically significant correlation between these categories (p value: 0.043) (Table 3). Additionally, whether there is a relationship between seeing the choice of recycled/recyclable products as critical role and choosing these products is examined and no statistically significant correlation is found.

When the relationship between recyclable and second hand product selection in the architectural design stage in terms of waste reduction is examined, a weak, positive and statistically significant correlation is found (p value: 0.04) (Table 4).

Of the designers, 83% said that the waste generated during construction can be controlled in the design stage, but that the possibilities for the disassembly and demolition stage were lower (Fig. 7). Although this outcome is consistent with their levels of considering preventing/reducing waste during the construction, use and disassembly/demolition stages (Fig. 6), the percentages are different. These findings indicate that the designers are aware of the controllability of waste amounts in the design stage, but cannot put it into practice.

When the relationship between the statements (the designers' levels of consideration in the design stage about preventing, reducing and disposing of C&D waste during buildings' construction stage - the designers' opinions about using the design stage to control the waste amounts generated in the construction stage) is examined, a weak, positive and statistically significant correlation is found (p value: 0.032) (Table 5).

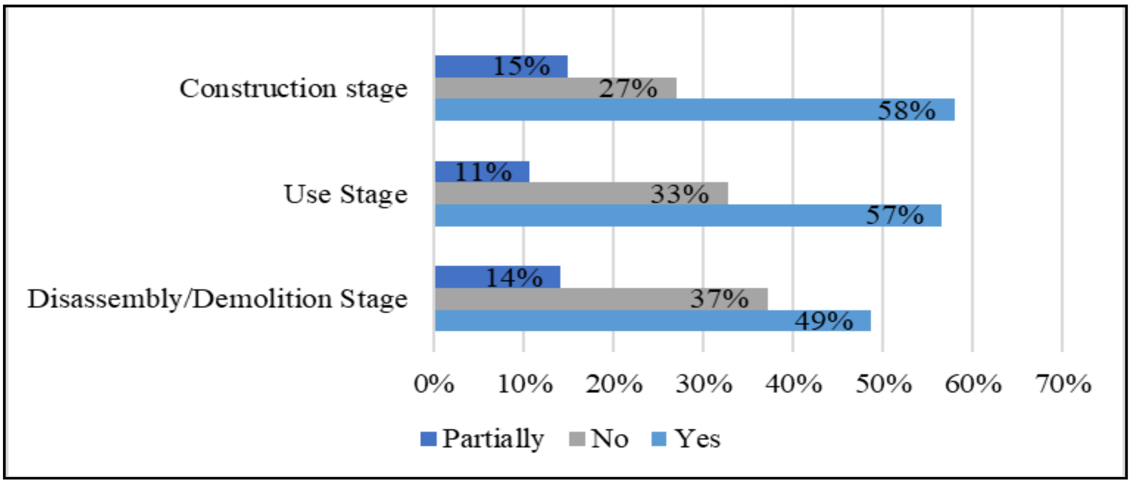

Fig. 6. Designers' consideration level

Table 3. Architects' role in selecting second hand building products

Variable	*n*	*mean*	*Std. Dev.*	*S. E. Mean*	*Lower Limit*	*Upper Limit*
Is second hand product selection one of the critical roles of the architect?	91	0.1319	0.3402	0.0357	0.0610	0.2027
Do you prefer second hand products?	91	1.7692	0.6511	0.0683	1.6336	1.9048

Table 4. The relationship between second hand and recyclable building product selection

Variable	*n*	*mean*	*Std. Dev.*	*S. E. Mean*	*Lower Limit*	*Upper Limit*
Do you prefer recyclable products?	91	1.1538	0.4927	0.0516	1.0512	1.2565
Do you prefer second hand products?	91	1.7692	0.6511	0.0683	1.6336	1.9048

The same relationship between in terms of use and disassembly/demolition stages are assessed. There is no statistically significant correlation in between these relationships (for use stage, p value: 0.056; for disassembly/demolition stage, p value: 0.524).

The views of the respondents were sought about which stage waste could be prevented/reduced. Majority of the respondents (57%) indicated that when planning to prevent/reduce wastage, all the stages of buildings should be taken into consideration. Of the respondents, 40% indicated that the prevention/reduction of waste should only be taken into consideration during the construction phase. Of them, 36% indicated that waste reduction should be considered at the design stage, 36% further indicated that the reduction of waste should be considered at the renovation/maintenance phase, with 32% also indicating that the reduction of waste is necessary at the disassembly/demolition phase. The finding from the study further revealed that reducing waste is an on-site activity that can be applied during construction stage.

Concerning the responsibilities of the respondents in the reduction of waste, 52% indicated that they have full responsibilities towards the reduction of waste, 9% indicated partial responsibilities towards the reduction of waste. This is also supported by the finding about the importance of C&D waste reduction in the design stage, a response given by 66% of the respondents. This result indicates that the designers have high awareness levels about waste prevention in the design stage. On the other hand, only 36% responded that the design stage is important for reducing waste amounts, which is contradictory.

The respondents were again asked to indicate the most important and effective parameters in the management of waste. Of the designers, 50% indicated that materials recycling is the most important parameter, followed by 24% who indicated reusing the waste as an important parameter. However, 13% each indicated that reduction at source and classification and storage could also be important parameters. This finding corroborates that reported in literature which indicated that separation at the source and recovery activities are not sufficient ways of reducing wastage of materials in Turkey (Başar, 2007). All the participants (100%) said that use of second hand and recycled building products is important to save the environment and resources and that awareness about them should be raised in society. Setting up facilities for the recycling and reuse of C&D waste is also a crucial way to create new employment opportunities.

The opinions of the participants about effective C&D waste management were also surveyed. Most of them (71%) said that rules and regulations at the national and local scales should be developed. The most commonly offered suggestions were: training about waste management, developing waste separation techniques and methods in construction site, paying attention to C&D waste reduction in designs and allocating specialized sections in construction and demolition contracts concerning waste management, in this order (Fig. 8). Building Information Modelling (BIM) software should also be used for optimization. Coordination between project owners, design teams and construction teams was also listed as an important parameter.

5. Conclusions

Studies of the activities of the construction industry are important for the natural environment, the health of living beings and nations' economies. This is clearer when the negative impacts of C&D waste caused by the construction, use, disassembly/demolition of buildings are considered. Although various studies of C&D waste are available in global literature, studies of the opinions of architects with different levels of business capacities were not encountered in the Turkish literature. Thus, conducting studies that emphasize the responsibility of architects and encourage them to prevent/reduce C&D waste is significant. Designing out waste can be achieved as soon as architects become aware about of their contribution to waste reduction in the design stage.

Table 5. The consideration, prevention and control of waste in design

<table>
<tr><th colspan="2">Variable</th><th>n</th><th>mean</th><th>Std. Dev.</th><th>S. E. Mean</th><th>Lower Limit</th><th>Upper Limit</th></tr>
<tr><td rowspan="3">the designers' levels of consideration in the design stage about preventing / reducing / disposing of C&D waste during …</td><td>Construction Stage</td><td>91</td><td>1.5604</td><td>0.7632</td><td>0.0800</td><td>1.4015</td><td>1.7194</td></tr>
<tr><td>Use Stage</td><td>91</td><td>1.5165</td><td>0.7049</td><td>0.0739</td><td>1.3697</td><td>1.6633</td></tr>
<tr><td>Disassembly/Demolition Stage</td><td>91</td><td>1.6264</td><td>0.7094</td><td>0.0744</td><td>1.4786</td><td>1.7741</td></tr>
<tr><td rowspan="3">the designers' opinions about using the design stage to control the waste amounts generated in the …</td><td>Construction Stage</td><td>91</td><td>1.3407</td><td>0.6867</td><td>0.0720</td><td>1.1976</td><td>1.4837</td></tr>
<tr><td>Use Stage</td><td>91</td><td>1.3077</td><td>0.5905</td><td>0.0619</td><td>1.1847</td><td>1.4307</td></tr>
<tr><td>Disassembly/Demolition Stage</td><td>91</td><td>1.3736</td><td>0.6262</td><td>0.0656</td><td>1.2432</td><td>1.5040</td></tr>
</table>

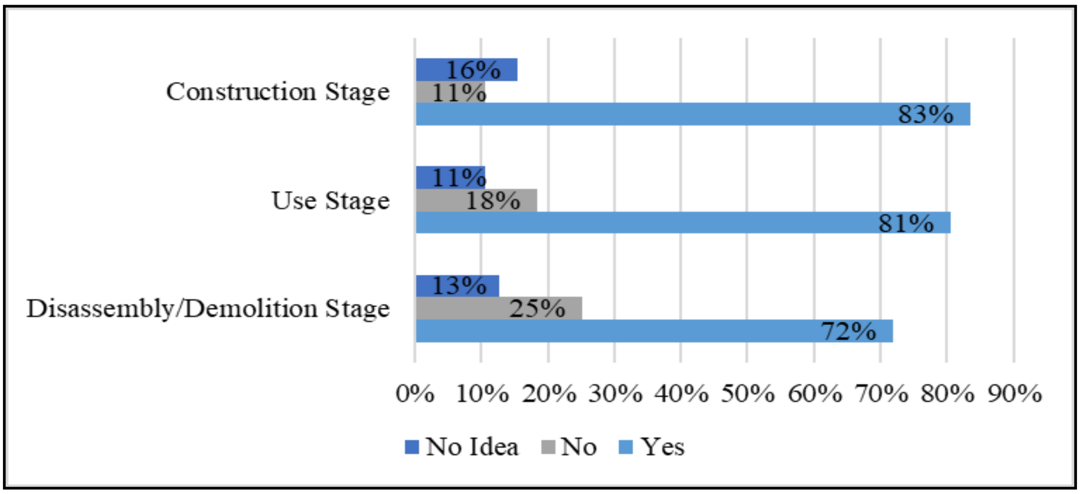

Fig. 7. Designers' opinions in controlling waste through designs

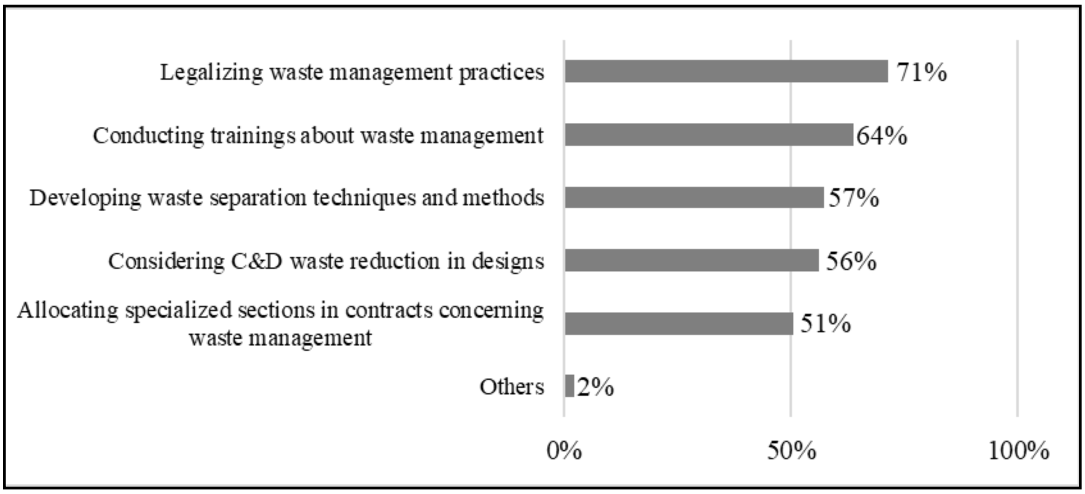

Fig. 8. Designers' opinions about C&D waste management

This study administered a survey to determine designers' levels of awareness about C&D waste. More than 50% of the participants expressed that they take preventing, reducing and properly disposing of C&D waste into consideration in their designs. Of them, 49% also said that they consider the waste generated during buildings' disassembly/demolition stage in the design stage. Although 81% of the participants associated the largest amount of waste with the disassembly/demolition stage, they do not pay attention to this in the design stage, which indicates contradictory attitudes.

Hence, there is a clear need to raise designers' awareness levels, and this can be ensured by the guidance of scientific studies. Architectural designs should also be examined in terms of C&D waste generation potential by supervising systems, in which local authorities can take on key tasks.

The role of building users is also critical in C&D waste management along with the awareness levels of designers and other stakeholders in the construction industry. The results of this study indicate that designers are eager to use recyclable and recycled building products; however, they reject the use of second hand products. The designers also said that even if there were an improved market for second hand and recycled building products in Turkey, they would still prefer recycled building products and remain reluctant to use second hand building products. Reuse is the second most important waste management strategy after preventing/reducing C&D waste. Hence, solutions should be found to raise the low level of ambition to reuse building products in Turkey. Demand for reused building products can be increased by regulating standards and use conditions, ensuring better maintenance and repair facilities, and setting up retail stores for presentation and sales.

Acknowledgements

This work was supported by Scientific Research Projects Coordination Unit of Erciyes University. Project Number: FBA-2016-6627.

Appendix

Question Group 1 - Definition of Waste

QG1-1. Which of the following options can be thought as waste in building production? (you can choose more than one option)

[ ] Excavation soil
[ ] Construction waste
[ ] Maintenance/repair/renovation waste
[ ] Disassembly/demolition waste
[ ] Asphalt work

QG1-2. Which stage of buildings' life cycles generates most waste?
[ ] Construction stage
[ ] Use stage
[ ] Disassembly/demolition stage

QG1-3. Which is the largest amount of waste generated in the building production? (you can choose more than one option)
[ ] Concrete
[ ] Wood
[ ] Excavated soil
[ ] Clay roof tiles or brick
[ ] Metal

Question Group 2 - Causes of Waste Production

QG2-1. Please, rate the causes of waste due to the design decisions.

(1=not a cause of waste, 2=insignificant cause of waste, 3=cause of waste, 4=significant cause of waste, 5=primary cause of waste)

	1	2	3	4	5
Clients' last minute requests for changes					
Architects' lack of knowledge or experience					
Insufficient design data					
Lack of coordination and communication					
Lack of modularization					
Improper details					
Delaying drawing revisions					
Improper building product selection					

QG2-2. Please, rate the causes of waste during the construction stage.

(1=not a cause of waste, 2=insignificant cause of waste, 3=cause of waste, 4=significant cause of waste, 5=primary cause of waste)

	1	2	3	4	5
Unused materials and products					
Waste caused by improper cutting and shaping during construction					
Improper storage areas and methods					
Climatic conditions					
Delayed information about the dimensions of building products					
Ordering excessive quantities of products					
Improper workmanship and practices					
Lack of knowledge and experience					

QG2-3. Please, rate the causes of waste during the use stage.

(1=not a cause of waste, 2=insignificant cause of waste, 3=cause of waste, 4=significant cause of waste, 5=primary cause of waste)

	1	2	3	4	5
Designing without considering users' needs					
Lack of flexibility in design					
Changes in building product trends					
Improper details that prevent maintenance, repair and renovation					
Non-durable building products					
Lack of awareness					
Deterioration and degradation of building products					

QG2-4. Please, rate the causes of waste during the disassembly/demolition stage.

(1=not a cause of waste, 2=insignificant cause of waste, 3=cause of waste, 4=significant cause of waste, 5=primary cause of waste)

	1	2	3	4	5
Improper joints between construction products					
Lack of disassembly plan for buildings					
Lack of knowledge and experience,					
Lack of awareness					

Question Group 3 - The role of designers in the management of C&D waste

QG3-1. How would you react to deterioration of natural environment and the reduction of resources in building production?

[ ] Ecological design principles are important in my designs.

[ ] I choose recycled, recyclable and reusable products for my designs.

[ ] I try to warn and encourage those who are concerned.

[ ] I support organizations that work for environmental protection.

[ ] I am not interested.

QG3-2. What are the critical roles of designers in reducing C&D waste during design stage? (you can choose more than one option)

[ ] Making suggestions to clients

[ ] Considering waste reduction during the design stage

[ ] Improving design practices

[ ] Paying attention to selecting recyclable materials for designs

[ ] Selecting recycled materials for designs

[ ] Selecting second hand products for designs

[ ] Other (please explain)

QG3-3. In the design stage, do you take into account preventing, reducing and disposing of construction waste which is generated during the construction stage of buildings?

[ ] Yes
[ ] No
[ ] Partly (please explain)

QG3-4. In the design stage, do you take into account preventing, reducing and disposing of C&D waste which is generated during the use stage of buildings?

[ ] Yes
[ ] No
[ ] Partly (please explain)

QG3-5. In the design stage, do you take into account preventing, reducing and disposing of demolition waste which is generated during the disassembly/demolition stage of buildings?

[ ] Yes
[ ] No
[ ] Partly (please explain)

QG3-6. Do you prefer recyclable products in the design stage?

[ ] Yes
[ ] No
[ ] Partly (please explain)

QG3-7. Do you prefer recycled products in the design stage?

[ ] Yes
[ ] No
[ ] Partly (please explain)

QG3-8. Do you prefer second hand products in the design stage?

[ ] Yes
[ ] No
[ ] Partly (please explain)

QG3-9. Can waste which is generated during construction stage be controlled in the design stage?

[ ] Yes
[ ] No
[ ] No idea

QG3-10. Can waste which is generated during use stage be controlled in the design stage?

[ ] Yes
[ ] No
[ ] No idea

QG3-11. Can waste which is generated during disassembly/demolition stage be controlled in the design stage?

[ ] Yes
[ ] No
[ ] No idea

QG3-12. During which stage could waste be prevented/reduced? (you can choose more than one option)

[ ] Design stage
[ ] Construction stage
[ ] Renovation/maintenance stage
[ ] Disassembly/demolition stage
[ ] All of the stages

QG3-13. Do you have any responsibilities in the reduction of waste in your design?

[ ] Yes
[ ] No
[ ] Partly

QG3-14. Please, indicate the most important and effective parameters in the management of waste?

[ ] Reduction at source
[ ] Recycling
[ ] Reusing
[ ] Classification and storage
[ ] Incineration

QG3-15. Do you wish the community to be more conscious about recycling and recovery?

[ ] Yes
[ ] No
[ ] No idea

QG3-16. How do you think effective C&D waste management can be administered? (you can choose more than one option)

[ ] Legalizing waste management practices
[ ] Considering C&D waste reduction in designs
[ ] Developing waste separation techniques and methods
[ ] Conducting trainings about waste management
[ ] Allocating specialized sections in contracts concerning waste management
[ ] Other (please explain)

QG3-17. If a second hand and/or a recycled product market developed in Turkey, would you prefer these products in your designs?

	Yes	No	Maybe
Second hand products			
Recycled products			

QG3-18. How effective is the choice of second hand and recycled building products to protect the natural environment and resources?

[ ] Very effective
[ ] Effective
[ ] No effect
[ ] No idea

References

Akhtar A., Sarmah A.K., (2018), Construction and demolition waste generation and properties of recycled aggregate concrete: a global perspective, *Journal of Cleaner Production*, **186**, 262-281.

Başar B., (2007), *A project about recycling of constructional solid waste in Turkey* (in Turkish), MSc Thesis, Gebze Technical University, Kocaeli, Turkey.

Baldwin A., Poon C.S., Shen L.Y., Austin S., Wong I., (2009), Designing out waste in high-rise residential buildings: analysis of precasting and prefabrication methods and traditional construction, *Renewable Energy*, **34**, 2067-2073.

Ballard G., Zabelle T., (2000), Project definition white paper 9, LCI, Lean Construction Institute, On line at: http://p2sl.berkeley.edu/wp-content/uploads/2016/03/W009-Ballard_Zabelle-2000-Project-Definition-LCI-White-Paper-9.pdf.

Bossink A.G., Brouwers H.J.H., (1996), Construction waste: quantification and source evaluation, *Journal of Construction Engineering and Management*, **122**, 55-60.

Chandrakanthi M., Ruwanpura J., Hettiaratchi P., Prado B., (2002), *Optimization of the Waste Management for Construction Projects using Simulation*, Proc. 2002 Winter Simulation Conf., San Diego, USA, 1771-1777.

Coşgun N., Güler T., Doğan B., (2009), Architect's role in C&D waste prevention/reduction (in Turkish), *Mimarlık*, **348**, 75-78.

Couto J.P, Mendonca P., Reis A.P., (2018), Prefabricated building systems: evaluation of the construction practitioners' perception on the environmental and economic benefits, *Environmental Engineering and Management Journal*, **17**, 2103-2115.

Coventry S., Guthrie P., (1998), *Waste Minimization and Recycling in Construction: Design Manual*, Construction Industry Research & Information Association, London, United Kingdom.

Dahlbo H., Bacher J., Lahtinen K., Jouttijarvi T., Suoheimo P., Mattila T., Sironen S., Myllymaa T., Saramaki K., (2015), Construction and demolition waste management-a holistic evaluation of environmental performance, *Journal of Cleaner Production*, **107**, 333-341.

DEFRA, (2019), UK statistics on waste, Government Statistical Service, On line at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/784263/UK_Statistics_on_Waste_statistical_notice_March_2019_rev_FINAL.pdf.

Dorsthorst B.J.H., Kowalczyk T., (2002), *Design for Recycling*, Proc. CIB Task Group 39-Deconstruction Annual Meeting, Karlsruhe, Germany, 71-81.

Ekanayake L.L., Ofori G., (2000), *Construction Material Waste Source Evaluation*, Proc. 2nd Southern African Conf. on Sustainable Development in the Built Environment: Strategies for a Sustainable Built Environment, Pretoria, South Africa, 1-6.

EPD, (2016), Monitoring of solid waste in Hong Kong waste statistics for 2015, Environmental Protection Department, On line at: https://www.wastereduction.gov.hk/sites/default/files/msw2015.pdf

Eurostat, (2019), Waste statistics, European Statistics, On line at: https://ec.europa.eu/eurostat/statistics-explained/index.php/Waste_statistics#Total_waste_generation.

Faniran O.O., Caban G., (1998), Minimizing waste on construction project sites, *Engineering Construction and Architectural Management*, **5**, 182-188.

Gálvez-Martos J.L., Styles D., Schoenberger H., Zeschmar-Lahl B., (2018), Construction and demolition waste best management practice in Europe, *Resources Conservation and Recycling*, **136**, 166-178.

Gangolells M., Casals M., Forcada N., Macarulla M., (2014), Analysis of the implementation of effective waste management practices in construction projects and sites, *Resources Conservation and Recycling*, **93**, 99-111.

GBCA, (2018), Green Star overview, Green Building Council of Australia, On line at: http://www.gbca.org.au/green-star/green-star-overview/.

Greenwood R., (2003), *Construction Waste Minimization–Good Practice Guide*, Cardiff University, Centre for Research in the Built Environment, Cardiff, United Kingdom.

Higgins T.E., (1995), *Pollution Prevention Handbook*, 1st Edition, Lewis Publishers/CRC Press, Boca Raton, USA.

Innes S., (2004), *Developing Tools for Designing out Waste Pre-Site and Onsite*, Proc. Minimizing Construction Waste Conf.: Developing Resource Efficiency and Waste Minimization in Design and Construction, London, United Kingdom, 1-89.

Keys A., Baldwin A., Austin S., (2000), Designing to encourage waste minimization in the construction industry, Loughborough University Institutional Repository, On line at: https://dspace.lboro.ac.uk/dspace-jspui/handle/2134/4945

Li J., Tam V.W.Y., Zuo J., Zhu J., (2015), Designers' attitude and behaviour towards construction waste minimization by design: a study in Shenzhen, China, *Resources Conservation and Recycling*, **105**, 29-35.

Moreton A., Coffey V., Sadiqi Z., (2016), Training for reduction of design waste, *Proceedings of the ICE - Waste and Resource Management*, **169**, 123-130.

Oikonomou N.D., (2005), Recycled concrete aggregates, *Cement & Concrete Composites*, **27**, 315-318.

Osmani M., Glass J., Price A.D.F., (2008), Architect's perspectives on construction waste Reduction by Design, *Waste Management*, **28**, 1147-1158.

Polat G., Ballard G., (2004), *Waste in Turkish Construction: Need for Lean Construction Techniques*, Proc. 12th Annual Conf. of the Int. Group for Lean Construction, Elsinore, Denmark, 1-14.

Poon C.S., Yu A.T.W., Jaillon L., (2004), Reducing building waste at construction sites in Hong Kong, *Construction Management and Economics*, **22**, 461-470.

Salgın B., (2015), *Design approaches to prevent/reduce C&D waste generated through the building life processes and a model suggestion (*in Turkish*)*, PhD Thesis, Yıldız Technical University, Graduate School of Natural and Applied Sciences, Istanbul, Turkey.

Simion I.M., Ghinea C., Maxineasa S.G., Taranu N., Bonoli A., Gavrilescu M., (2013), ecological footprint applied in the assessment of construction and demolition waste integrated management, *Environmental Engineering and Management Journal*, **12**, 779-788.

Taha M., (2015), What a waste: solid waste management and the Malaysian perspective on construction waste generation and management, On line at: http://www.swcorp.gov.my/index.php/en/.

Townsend T., Anshassi M., (2017), Benefits of construction and demolition debris recycling in the United States, On line at: https://cdrecycling.org/site/assets/files/1050/cdra_benefits_of_cd_recycling_final_revised_2017.pdf.

Villoria Saez P., Del Rio Merino M., Gonzalez A.S.A., Porras-Amores C., (2013a), Best practice measures assessment for construction and demolition waste management in building constructions, *Resources Conservation and Recycling*, **75**, 52-62.

Villoria Saez P., Del Rio Merino M., Romaniega Piñeiro S., (2013b), *Assessing Construction and Demolition Waste on Masonry Works to Avoid Future Generation*, Proc.

1st Intern. Congress on Sustainable Construction and Eco-Efficient Solutions, Sevilla, Spain, 29-30.

Villoria Saez P., Del Rio Merino M., Porras-Amores C., Astorqui J.S.C., Pericot N.G., (2019), Analysis of best practices to prevent and manage the waste generated in building rehabilitation works, *Sustainability*, **11**, 1-14.

Wang J., Li Z., Tam V.W.Y., (2015), Identifying best design strategies for construction waste minimization, *Journal of Cleaner Production*, **92**, 237-247.

Wang X, Zheng L, Wu H, Duan H, Wang J, (2016), *Quantity and Treatment Status of C&D Waste in China*, Proc. Intern. Conf. on Construction and Real Estate Management 2016, Edmonton, Canada, 624-630.