International Journal of BIM and Engineering Science

♦ ISSN: 2571-1075 Vol: 10, No. 02, 2025 ♦ PP. 34–39
Article DOI: https://doi.org/10.54216/IJBES.100206

FULL LENGTH ARTICLE

Concrete Waste Management Based on BIM for Syrian Buildings

Mohammed Hasan[1,*] **Lama Saoud**[2]

[1] Student of Building Information Modeling and Management Master Program, Syrian Virtual University, Damascus, Syria
[2] Assistant Professor, Engineering and Construction Management Department, Faculty of Civil Engineering, Tishreen University, Lattakia, Syria

Emails: mohammed_ali_hasan_158849@svuonline.org · lama.saoud@tishreen.edu.sy

Received: October 19, 2024 Revised: December 22, 2024 Accepted: January 18, 2025 ⋆ Corresponding author

ABSTRACT

This study focuses on the management of concrete waste from demolished buildings. It is a crucial issue globally and particularly in Syria due to the significant amounts of concrete waste resulting from the long war and the February 6, 2023 earthquake. The research aims to promote sustainability and resource conservation in the Syrian construction sector by introducing a method for managing demolition waste using Building Information Modeling (BIM) technology. A case study was conducted on a residential building in the old city of Homs that was demolished due to the war. The building was modeled using Revit software, and mathematical modeling was applied to calculate and manage the demolition waste related to the building's structural frame. The study revealed potential economic savings of up to 4.2% of the total cost of the building's concrete framework through recycling the structural-frame waste (coarse aggregate and fine aggregate only). Furthermore, the study estimated the financial returns that could be realized from managing demolished concrete waste across the entire Homs Governorate.

Keywords: Recycling ▪ Sustainability ▪ Construction Waste Management ▪ Building Information Modeling (BIM) ▪ Building Waste Management Using BIM Technology

1. INTRODUCTION

In light of the prolonged conflict Syria has experienced over the past decade, the country has faced immense destruction to its infrastructure, including buildings, facilities, industrial zones, and archaeological sites. This devastation was further exacerbated by catastrophic earthquakes, expanding the destruction to nearly all Syrian regions. Consequently, it has become essential to develop a suitable strategy for managing the vast amounts of rubble and exploring their use as sustainable materials in future reconstruction efforts.

The construction industry is increasingly focusing on eliminating waste and inefficiency to improve quality and profitability [1]. The industry, in all its forms, is among the most resource-wasting and waste-producing sectors and generates approximately 17% of the total waste produced globally [2]. As projects have evolved and increased in complexity, these issues have intensified and become more pressing [3]. However, recent technological advances in construction—including Building Information Modeling (BIM) and Virtual Design and Construction (VDC)—make these challenges more manageable. As sustainability concepts and standards have developed within the Architecture, Engineering, and Construction (AEC) sector, the focus on sustainable materials and recycling practices has grown significantly.

In Syria, demolition waste accumulated during years of conflict poses a major challenge to reconstruction and development. As of January 2022, total damages across cities and sectors were estimated at between \$8.7 billion and \$11.4 billion, with approximately 68% of those damages (about \$5.8–7.8 billion) attributed to physical infrastructure. The World Bank estimated a further \$5.1 billion in direct physical damage from the February 6, 2023 earthquake [4]. This situation presents an enormous amount of waste that must be effectively managed and utilized. Reconstructing cities requires a comprehensive and innovative methodology for repairing damage or reusing debris from affected buildings. Such an approach can reduce environmental impacts while providing cost savings, because economic factors play a central role in reconstruction [5].

Construction-waste management supported by BIM technology therefore emerges as a promising solution aligned with global standards because of its positive economic and environmental effects and its potential to create new employment opportunities. BIM already plays a significant role in the construction industry and has proved beneficial in addressing many challenges faced by AEC projects. Researchers have investigated construction-waste management during the design and construction phases [6, 7, 8]; however, research focused specifically on demolition-waste management remains limited.

Despite the enormous amount of demolition waste in Syria and growing global interest in maximizing its value as a sustainable material, relatively little research has addressed its management and economic return. This paper presents a practical methodology for managing demolished concrete waste from building structural frames. The method is applied to a residential building affected by the war in Homs Governorate and modeled in Revit 2018. The economic gains achievable through recycling demolished concrete are then calculated.

2. REFERENCE STUDIES

The Syrian war caused extensive destruction of infrastructure and buildings, making it necessary to consider how debris from demolished structures can be managed, sorted, and reused during reconstruction. Hassan et al. [9] presented a method for estimating the expected volume and composition of debris in several Syrian cities. Their work discussed recycling costs and anticipated profits and proposed a work plan and technological alternative for managing the recycling process.

Another study indicated that a high percentage of building rubble in Syria could be reused, reducing the transportation and disposal costs of unwanted debris, minimizing environmental pollution, and generating economic value. Applying recycling and rehabilitation techniques in Syria could save approximately $17 billion [5]. In general, little research has integrated BIM with Demolition Waste Management (DWM) [10, 11, 7]. Budget and time constraints may discourage practitioners from adopting BIM in DWM without modern construction documentation, while the lack of BIM-compatible DWM functions and interoperability between BIM and waste-management tools remains a challenge [10].

Noaman [12] discussed strategies for managing construction waste in Iraqi reconstruction efforts, seeking an effective and economical approach while limiting negative environmental impacts. A field survey in Mosul determined the volume and nature of accumulated construction waste, which was evaluated, classified, and assessed for reuse and recycling. The economic comparison found a 12.9% saving in the reconstruction cost of the University of Mosul presidency and a 37.3% saving in supplying natural stone for construction work at the Al-Hadba Minaret.

The principal quantitative methods reviewed for estimating building-demolition waste are summarized below.

- **Estimation according to physical-planning models.** Lau et al. [13] proposed a method that estimates construction-waste volume from the physical arrangement of waste on site. Four forms—stored, aggregated, scattered, and stacked—record waste at different project stages. For example, stockpiled waste is assumed to have the form of a pyramid with a rectangular base. The method lacks accuracy and is not directly applicable to all demolition forms.

- **Estimation based on building components.** Jalali [14] introduced the “Component Index” approach, in which the amount of Construction and Demolition (C&D) waste is estimated from the type and quantity of building components. A component is the smallest specific and independent construction unit used for data collection and waste estimation. An index for each component estimates different wastes, such as wood, concrete, and reinforcing steel. The approach relies heavily on detailed spreadsheets and labor-intensive manual measurements and updates, making practical implementation difficult.

- **BIM-based estimation and planning of demolition and renovation waste.** Cheng and Ma [11] developed a system for estimating and planning Demolition and Renovation (D&R) waste. A Revit plug-in allows multidisciplinary information to be incorporated into a single digital building model. The system was demonstrated on a 47-story residential building in Hong Kong and uses volume-change factors based on the demolition-increase factors in the Andalusian Construction Costs Database [15]. Restricted access to the software limits the evaluation and use of this model.

- **Area-based estimation.** Poon et al. [16] presented the “Waste Index” method for estimating the total amount of new-construction waste. The index is the quantity, by volume or weight, of construction waste generated per square meter of gross floor area or activity area. Because it treats building area as the primary factor, the method is relatively inaccurate for projects whose waste characteristics differ substantially.

- **Estimation from construction databases.** Several regional models use construction-cost databases to estimate waste quantities. A prominent example is the Spanish model presented by Solis-Guzman et al. [17], based on the Andalusian Construction Costs Database (BCCA) [15]. It estimates waste from construction and demolition activities using four parameters: Apparent Construction Volume (VAC), Apparent Demolition Volume (VAD), Apparent Wreckage Waste Volume (VAR), and Apparent Package Waste Volume (VAE). Statistical analysis of more than 100 residential projects established relationships among these parameters. For example, the VAC of an element is converted to VAD using a factor C_T representing its volume increase after demolition. For concrete columns, $C_T = 1.15$, indicating an average volume increase of 15% after demolition.

The Spanish model is adopted in this research because it assigns an individual factor to each construction element, provides accurate results, and is flexible and straightforward to use.

3. RESEARCH METHODOLOGY

The study began with a review of prior work to select an appropriate quantitative model. A residential building damaged during the war in the old city of Homs was then chosen as a case study and modeled using Revit 2018. The amount of concrete used in the building was quantified, after which the Spanish model [17] was applied to estimate the volume of demolished concrete.

Allowable reference ratios for recycled aggregate [18, 19] were used to calculate the quantity of recycled aggregate that could be incorporated into the building's reconstruction. The current recycling cost for $1\,\text{m}^3$ of concrete waste was estimated from the work of Hassan et al. [9]. The monetary return and percentage saving produced by using the permissible recycled-aggregate ratios were calculated, followed by the financial return from selling the remaining recycled aggregate.

These calculations provided an estimate of the financial return from recycling $1\,\text{m}^3$ of demolished concrete. The volume of debris in Homs reported in [9], together with the proportion of demolished concrete reported in [20], was then used to estimate the potential financial return from managing demolished concrete throughout Homs Governorate.

3.1 Case Study

The residential-building case study was selected because of the large number of demolished buildings in Syria. After obtaining two-dimensional CAD drawings from the Syrian Engineers Syndicate branch in Homs Governorate, the author created a three-dimensional model of the building's structural frame in Revit.

The building is located in the Bab al-Dreib area of the old city of Homs. It has five levels: a basement, a ground floor for commercial use with canopies, and three residential floors. Its overall dimensions are approximately $16.7\,\text{m} \times 32.2\,\text{m}$, with a floor area of about $450\,\text{m}^2$ and a total height of 17.15 m. The basement is 2.8 m high, the ground floor is 5 m high, and each residential floor is 3.3 m high. Figure 1 shows the resulting Revit model.

Figure 1. Three-dimensional view of the building model using Revit (2018).

4. RESULTS AND DISCUSSION

4.1 Extraction of the Bill of Quantities

The Bill of Quantities (BOQ) covered the concrete used in the structural work—foundations, columns, slabs, and load-bearing walls—together with the estimated cost of completing these works. Interviews with supervising engineers and contractors indicated that, in July 2024, one cubic meter of reinforced concrete with a strength of 350 and a reinforcement ratio of 100 kg cost approximately $3{,}200{,}000\,\text{SYP}/\text{m}^3$ in the Syrian construction market, including materials, labor, and wastage. Figure 2 presents the schedules extracted from Revit, and Table 1 summarizes the resulting quantities and costs.

Table 1. Quantities and cost estimates of the building's concrete works.

Structural element	Quantity and unit	Cost
Foundations	$108.49\,\text{m}^3$	347,160,754.55 SYP
Columns	$114.79\,\text{m}^3$	367,323,391.54 SYP
Slabs	$361.27\,\text{m}^3$	1,156,069,301.29 SYP
Load-bearing walls	$298.55\,\text{m}^3$	955,367,109.14 SYP
Total	**883**.1 m^3	2,825,920,556.52 **SYP**

4.2 Estimation of Expected Demolition-Waste Volume

The Spanish model [17] was applied to the quantities extracted from Revit 2018. The Apparent Construction Volume (VAC) for item i is calculated as

$$V_{AC,i} = Q_i C_{C,i}, \tag{1}$$

where $V_{AC,i}$ is the apparent construction volume in m^3, Q_i is the quantity of the element in its specific unit, and $C_{C,i}$ is the conversion ratio from that unit to apparent construction volume.

The Apparent Demolition Volume (VAD) is calculated from VAC as

$$V_{AD,i} = V_{AC,i} C_{T,i} = Q_i C_{C,i} C_{T,i}, \tag{2}$$

where $V_{AD,i}$ is the apparent demolition volume and $C_{T,i}$ converts VAC to VAD. According to [12], the C_T factors for foundations, columns, beams, concrete walls, and slabs are 1.01, 1.15, 1.25, 1.18, and 1.20, respectively. Applying Eqs. (1) and (2) gives the values in Table 2.

Table 2. Estimated volume of concrete waste for the building.

No.	Waste type	Q_i (m^3)	$C_{C,i}$ (m^3/m^3)	$C_{T,i}$	$V_{AC,i}$ (m^3)	$V_{AD,i}$ (m^3)
1	Foundations	108.49	1	1.01	108.49	109.57
2	Columns	114.79	1	1.15	114.79	132.01
3	Load-bearing walls	298.55	1	1.18	298.55	352.29
4	Slabs	361.27	1	1.20	361.27	433.52
	Total apparent volume of demolished concrete					**1027.4**

4.3 Savings from Recycled Aggregates

The residential-building model produces $1027.4\,\text{m}^3$ of concrete demolition waste. Revit quantities show that the build-

<Structural Framing Schedule>

A	B	C	D
Type	Count	Volume	Cost Estimation
B1 70x25	112	36.00 m^3	115186234.49
B1 70x25: 112		36.00 m^3	115186234.49
B2 80x25	109	42.94 m^3	137412140.88
B2 80x25: 109		42.94 m^3	137412140.88
B3 35x25	223	28.54 m^3	91332248.63
B3 35x25: 223		28.54 m^3	91332248.63
B4 20x25	217	12.56 m^3	40202016.13
B4 20x25: 217		12.56 m^3	40202016.13
Rib (15/18)x25	733	68.56 m^3	219392347.11
Rib (15/18)x25: 733		68.56 m^3	219392347.11
Grand total: 1394		188.60 m^3	603524987.24

<Floor Schedule>

A	B	C	D	E	F
Type	Level	Area	Default Thickness	Volume	Cost Estimation
Cover Slab 5cm	00-Foundation	452 m^2	0.05 m	22.58 m^3	72267918.95
00-Foundation: 1		452 m^2		22.58 m^3	72267918.95
Cover Slab 5cm	01-Ground	409 m^2	0.05 m	20.46 m^3	65466913.08
01-Ground: 1		409 m^2		20.46 m^3	65466913.08
Cover Slab 5cm	02-Shed	100 m^2	0.05 m	5.01 m^3	16023905.32
Cover Slab 5cm	02-Shed	79 m^2	0.05 m	3.93 m^3	12572650.30
02-Shed: 2		179 m^2		8.94 m^3	28596555.62
Cover Slab 5cm	03-First	450 m^2	0.05 m	22.48 m^3	71920035.27
03-First: 1		450 m^2		22.48 m^3	71920035.27
Cover Slab 5cm	04-Second	450 m^2	0.05 m	22.48 m^3	71920038.10
04-Second: 1		450 m^2		22.48 m^3	71920038.10
Cover Slab 5cm	05-Third	450 m^2	0.05 m	22.48 m^3	71920038.10
05-Third: 1		450 m^2		22.48 m^3	71920038.10
Slab 20cm	06-Forth	199 m^2	0.2 m	39.89 m^3	127635460.17
Cover Slab 5cm	06-Forth	250 m^2	0.05 m	12.49 m^3	39958255.58
06-Forth: 2		449 m^2		52.37 m^3	167593715.75
Cover Slab 5cm	07-Roof	18 m^2	0.05 m	0.89 m^3	2859099.18
07-Roof: 1		18 m^2		0.89 m^3	2859099.18
Grand total: 10		2855 m^2		172.67 m^3	552544314.05

<Structural Column Schedule>

A	B	C	D
Type	Count	Volume	Cost Estimation
C1 30x50	12	11.97 m^3	38313600.00
C1 30x50: 12		11.97 m^3	38313600.00
C1 L 80x80	17	23.25 m^3	74401870.08
C1 L 80x80: 17		23.25 m^3	74401870.08
C2 30x50	84	40.87 m^3	130796721.47
C2 30x50: 84		40.87 m^3	130796721.47
C2 30x60	84	38.69 m^3	123811200.00
C2 30x60: 84		38.69 m^3	123811200.00
Grand total: 197		114.79 m^3	367323391.54

<Wall Schedule>

A	B	C	D
Type	Width	Volume	Cost Estimation
Retaining w30	0.3 m	121.40 m^3	388495251.96
Retaining w30: 56		121.40 m^3	388495251.96
W 30	0.3 m	177.15 m^3	566871857.18
W 30: 52		177.15 m^3	566871857.18
Grand total: 108		298.55 m^3	955367109.14

<Structural Foundation Schedule>

A	B	C	D
Type	Foundation Thickness	Volume	Cost Estimation
F 30cm	0.3 m	2.54 m^3	8113531.50
F 30cm: 1		2.54 m^3	8113531.50
F 60cm	0.6 m	61.68 m^3	197368253.62
F 60cm: 1		61.68 m^3	197368253.62
F wall 60cm	0.6 m	44.27 m^3	141678969.42
F wall 60cm: 1		44.27 m^3	141678969.42
Grand total: 3		108.49 m^3	347160754.55

Figure 2. BOQ and cost estimates of the building's concrete works using Revit (2018).

ing's structural work requires $883.1\,\mathrm{m}^3$ of concrete. The standard concrete mix ratio used in Syrian engineering work is 1:2:4, representing one part cement, two parts sand, and four parts gravel. The building therefore requires approximately $725\,\mathrm{m}^3$ of coarse aggregate and $371\,\mathrm{m}^3$ of fine aggregate.

Up to 50% recycled coarse aggregate (RCA) can be used in place of natural coarse aggregate [18], while up to 30% recycled fine aggregate (RFA) can replace natural fine aggregate [19]. Reconstructing the same building could therefore use

$$0.5 \times 725 = 362.5\,\mathrm{m}^3$$

of recycled coarse aggregate and

$$0.3 \times 371 = 111.3\,\mathrm{m}^3$$

of recycled fine aggregate.

In 2019, recycling one cubic meter of rubble in Syria cost approximately 1440 SYP (equivalent to \$2.88) [9]. Considering inflation and the roughly thirty-fold increase in the exchange rate between 2019 and 2024, the estimated July 2024 cost was approximately $43{,}000\,\mathrm{SYP}/\mathrm{m}^3$. By comparison, coarse aggregate cost $110{,}000\,\mathrm{SYP}/\mathrm{m}^3$ and fine aggregate cost $290{,}000\,\mathrm{SYP}/\mathrm{m}^3$, excluding transportation.

The recycling cost of the aggregate used in reconstruction is

$$(362.5 + 111.3) \times 43{,}000 = 20{,}373{,}400 \text{ SYP}.$$

The expected return from replacing natural aggregate with the permissible quantities of recycled aggregate is

$$362.5 \times 110{,}000 + 111.3 \times 290{,}000 = 72{,}152{,}000 \text{ SYP}.$$

The net saving is therefore

$$\begin{aligned} N_s &= \text{expected return} - \text{recycling cost} \\ &= 72{,}152{,}000 - 20{,}373{,}400 \\ &= 51{,}778{,}600 \text{ SYP}. \end{aligned}$$

The percentage saving relative to the total cost of the required aggregate is

$$\begin{aligned} S_{v1} &= \frac{N_s}{725(110{,}000) + 371(290{,}000)} \times 100 \\ &= 27.6\%. \end{aligned}$$

The reconstructed building would use $362.5 + 111.3 = 473.8\,\mathrm{m}^3$ of the available concrete waste. This represents

$$\frac{473.8}{1027.4} \times 100 \approx 46\%,$$

leaving approximately 54% for other reconstruction projects or sale in the local construction market.

For calculation purposes, the remaining aggregate is assumed to be sold locally. Recycled-concrete aggregate can sell for 83.3–100% of the corresponding natural-aggregate price [9]. This study assumes prices of 90,000 SYP for coarse aggregate and 240,000 SYP for fine aggregate, averaging approximately $165{,}000\,\mathrm{SYP}/\mathrm{m}^3$. The profit from selling the remaining material is

$$165{,}000(1027.4 - 473.8) = 91{,}344{,}000 \text{ SYP}.$$

The total profit obtained by recycling the building's

$1027.4\,\mathrm{m}^3$ of concrete waste is

$$91{,}344{,}000 + 72{,}152{,}000 - (1027.4 \times 43{,}000) = 119{,}317{,}800 \text{ SYP}.$$

The approximate net return expected from recycling one cubic meter of concrete waste is

$$116{,}549{,}800/1027.4 \approx 116{,}000 \text{ SYP}/\mathrm{m}^3.$$

Finally, the saving relative to the total cost of the structural concrete work is

$$S_{v2} = \frac{119{,}317{,}800}{2{,}825{,}920{,}556.52} \times 100 \approx 4.2\%.$$

Although the model is simple and considers concrete alone, the results show that substantial financial savings could be achieved in Syria by recycling concrete, metals, bricks, gypsum, plastics, and other construction wastes.

For Homs Governorate, the estimated quantity of construction waste is 7.5 million tons [9]. Reinforced concrete represents approximately 58% of building debris [20], giving an expected concrete-waste mass of

$$0.58 \times 7{,}500{,}000 = 4{,}350{,}000 \text{ tons}.$$

At a reinforced-concrete bulk density of $2500\,\mathrm{kg/m^3}$, or $2.5\,\mathrm{tons/m^3}$, the corresponding volume is

$$4{,}350{,}000/2.5 = 1{,}740{,}000\,\mathrm{m}^3.$$

Using the estimated net return per cubic meter, the total approximate return from concrete recycling in Homs Governorate is

$$1{,}740{,}000 \times 113{,}000 = 201{,}840{,}000{,}000 \text{ SYP},$$

or approximately 202 billion Syrian pounds. All estimates and prices are based on prevailing Syrian construction-market prices in July 2024.

5. CONCLUSION

The study examined demolition-waste management using BIM and compared quantitative models for estimating construction-waste volume. The Spanish model was found to be the most flexible because its coefficients can be tested and modified to suit a region or country. Enormous quantities of debris are present in several Syrian governorates, and using this debris as a sustainable material can produce significant economic gains while preserving natural resources.

Based on the case-study model and reference studies, the research estimated the expected financial return from recycling the building's concrete waste. Recycling can save up to 4.2% of the total cost of the building's structural concrete work. The study also presented an approximate mechanism for estimating the return from recycling $1\,\mathrm{m}^3$ of demolished concrete. Using a previously reported estimate of construction-waste volume, the potential financial return across Homs Governorate was calculated at approximately 202 billion Syrian pounds.

This is a conservative estimate because the assumed selling prices for coarse aggregate (90,000 SYP) and fine aggregate (240,000 SYP) are lower than internationally reported recycled-aggregate prices of 83.3–100% of the corresponding natural-aggregate price. Transportation-cost savings were also excluded. Demolition-waste recycling therefore merits extensive study because of its potential contribution to the national economy and its role in preserving natural resources.

Funding

This research received no external funding.

Conflicts of Interest

The authors declare no conflict of interest.

REFERENCES

[1] M. U. Hossain, S. T. Ng, P. Antwi-Afari, and B. Amor, "Circular economy and the construction industry: Existing trends, challenges and prospective framework for sustainable construction," *Renewable and Sustainable Energy Reviews*, vol. 130, p. 109948, 2020.

[2] S. Coventry, B. Shorter, and M. Kingsley, *Demonstrating Waste Minimisation Benefits in Construction*, ser. CIRIA Publication C536. London, UK: CIRIA, 2001.

[3] S. Gupta, K. N. Jha, and G. Vyas, "Proposing building information modeling-based theoretical framework for construction and demolition waste management: Strategies and tools," *International Journal of Construction Management*, vol. 22, no. 12, pp. 2345–2355, 2022.

[4] World Bank, "Syria joint damage assessment 2022: Questions and answers," World Bank, 2023.

[5] A. A. Awad, F. A. A. Alkhalil, and A. A. Al-Dulaimy, "Innovative rehabilitation methodology of recycling buildings' debris in damaged districts (IRMIDD)," in *Proceedings of the Seventh International Jordanian Civil Engineering Conference (JICEC07)*, Amman, Jordan, 2017.

[6] L. B. Jayasinghe and D. Waldmann, "Development of a BIM-based web tool as a material and component bank for a sustainable construction industry," *Sustainability*, vol. 12, no. 5, p. 1766, 2020.

[7] Y.-C. Kim, W.-H. Hong, J.-W. Park, and G.-W. Cha, "An estimation framework for building information modeling (BIM)-based demolition waste by type," *Waste Management & Research*, vol. 35, no. 12, pp. 1285–1295, 2017.

[8] A. M. Yousfani, M. S. Raza, M. A. Moriyani, and T. H. Ali, "Building information modelling (BIM) based framework for construction and demolition waste estimation and management," *Jurnal Kejuruteraan*, vol. 35, no. 5, pp. 1101–1109, 2023.

[9] B. Hassan, J. Omran, and H. Ali, "Method of making the decision to find the optimal technological alternative to treat the demolition waste in the syrian case," *Tishreen*

University Journal for Research and Scientific Studies—Engineering Sciences Series, vol. 42, no. 1, pp. 385–402, 2020.

[10] D. Han, M. Kalantari, and A. Rajabifard, "Building information modeling (BIM) for construction and demolition waste management in australia: A research agenda," *Sustainability*, vol. 13, no. 23, p. 12983, 2021.

[11] J. C. P. Cheng and L. Y. H. Ma, "A BIM-based system for demolition and renovation waste estimation and planning," *Waste Management*, vol. 33, no. 6, pp. 1539–1551, 2013.

[12] A. S. Noaman, "Utilization of construction waste in reconstruction of war-destroyed projects," Master's thesis, University of Baghdad, Baghdad, Iraq, 2019.

[13] H. H. Lau, A. Whyte, and P. L. Law, "Composition and characteristics of construction waste generated by residential housing project," *International Journal of Environmental Research*, vol. 2, no. 3, pp. 261–268, 2008.

[14] S. Jalali, "Quantification of construction waste amount," in *Proceedings of the Sixth International Technical Conference on Waste*, Viseu, Portugal, Oct. 2007.

[15] Junta de Andalucía, Consejería de Vivienda y Ordenación del Territorio, *Base de Costes de la Construcción de Andalucía (BCCA)*, Junta de Andalucía, Seville, Spain, 2010.

[16] C. S. Poon, A. T. W. Yu, and L. H. Ng, *A Guide for Managing and Minimizing Building and Demolition Waste*. Hong Kong: Department of Civil and Structural Engineering, Hong Kong Polytechnic University, 2001.

[17] J. Solís-Guzmán, M. Marrero, M. V. Montes-Delgado, and A. Ramírez-de Arellano, "A spanish model for quantification and management of construction waste," *Waste Management*, vol. 29, no. 9, pp. 2542–2548, 2009.

[18] S. P. Patil, G. S. Ingle, and P. D. Sathe, "Recycled coarse aggregates," *International Journal of Advanced Technology in Civil Engineering*, vol. 2, no. 1, pp. 27–33, 2013.

[19] S. K. Kirthika and S. K. Singh, "Durability studies on recycled fine aggregate concrete," *Construction and Building Materials*, vol. 250, p. 118850, 2020.

[20] I. M. Srour, G. R. Chehab, M. El-Fadel, and S. Tamraz, "Pilot-based assessment of the economics of recycling construction demolition waste," *Waste Management & Research*, vol. 31, no. 11, pp. 1170–1179, 2013.