Technological strategies for recycling concrete block in Iraq

Israa Mohammad Al-Saffar¹, Osamah Abdulmunem Al-Tameemi²

¹ Department of Architecture, University of Baghdad, Baghdad, Iraq
² Department of Architecture, University of Baghdad, Baghdad, Iraq

i.alsaffar1104@coeng.uobaghdad.edu.iq
osamah.al-tameemi@coeng.uobaghdad.edu.iq

Abstract. Many concrete recycling strategies have emerged and many studies were devoted so as to find the best alternative to recycle concrete waste in order to produce recycled concrete aggregates (RCA) with a quality that competes with natural aggregates which contribute to concrete mixtures and try to establish effective and practical treatment methods in applications of new concrete mixtures, where concrete is considered a building material. Concrete is considered as one of the basic materials in architecture because of its durability and strength and contributes to the worldwide constructional movement and proved its robustness, durability and flexibility in architectural applications as it is considered one of the most widespread material and in the meantime forms a burden impact on the environment at the end of its function in the structures, so it was necessary to employ technological strategies in order to face this dilemma that began to deteriorate our environment.

Therefore, the research problem is determined as the need to clarify the concept of concrete recycling and concrete waste recycling in Iraq, due to lack of local knowledge, to produce recycled concrete aggregate, applicable in the fields of architecture and can be used in new concrete mixtures.

The aim of this research is to provide knowledge on different methods of recycling concrete from construction and demolition waste (C&DW) and the possibility of reusing its components in new concrete mixes, and to raise a debate about the reality of concrete waste in Iraq and the recycling concrete technology and suggest the most effective technological strategy to solve the Iraqi concrete waste crisis.

Keywords: Technological strategies, methods of recycling concrete, concrete waste in Iraq, architecture.

1. Introduction

Concrete structures represent one of the most durable and reliable structures in the world and the reason are due to the durability of their performance under different conditions, and concrete components are available all over the world. Today, cities are witnessing modernization and expansion, which results in the demolition of many concrete buildings and replacing them with new ones, as well as conflicts in some areas that have generated large quantities of rubble and concrete
waste. Therefore, it was necessary to move towards finding effective strategic and practical solutions to address the problem of generated concrete waste and save the environmental degradation caused by the demolished waste on one hand, and the irrational depletion of raw materials on the other hand.

2. **Technological strategy in architecture**

According to many literatures several definitions of technological strategy have been put forward. (Andrew 1980) believes that it is a type of decisions that define technological goals and the basic technological means to achieve those goals, and if we define technology as repeatable capabilities, whether these capabilities are included in procedures or equipment. The development and deployment of technologies in products, processes, or support activities should be included within the potential scope of a technology strategy. Even organizations where technology is not considered a critical competitive factor may benefit from a more strategic approach to managing their technical resources and activities [1], (Ford 1988) defined the relationship between technology and knowledge “to understand technology strategy it is necessary to make sure that the company has knowledge of the processes and what it can do.” Technology strategy focuses on this knowledge and these capabilities. It consists of policies, plans, and procedures for acquiring knowledge, managing that knowledge and the ability to exploit it to make a profit [2]; it is also considered a functional strategy i.e. a set of means and ends chosen for a specific job at work. Technological strategies do not differ from functional strategies such as (marketing, manufacturing, financial resources and human resources) that constitute the general business strategy. Technology strategies can be pursued through centralized control or through decentralized coordination. Thus, functional technology strategy/ centralized and decentralized technology strategy provides the possibility to create tension and conflict within the organization [3]; it is a definition of the organization's goals, principles, and tactics related to the specific techniques used by the organization [4]; it was referred to the technology strategy as a comprehensive plan consisting of principles, objectives and tactics for using technology to achieve organizational goals and may define specific technologies, and how these technologies will align with business objectives. The goal of the strategy is to determine how technology should be supported. Once a detailed plan is formulated, the technology strategy must be aligned with the technical structure of the organization. An organization's long-term technical strategy will not be realized if the information technology infrastructure does not support it. Thus, ensuring the development of a roadmap is critical to the success of a technology strategy. The roadmap will provide a technical perspective on the maturity of existing applications and infrastructure and should look at when software and hardware reach the end of their life span, as this will be a factor for implementing new technologies [5].

So technological strategy depends on technological means to achieve a plan consisting of technological principles and techniques to achieve goals and may be repeatable on technical procedures level or equipment level used by the organization, and focuses on the updating support of the data base and knowledge that are included through plans to reach, manage and assign the information, taking into account the replacement of end of life applications and hardware by new technical applications, and the technology strategy is either centralized control or decentralized coordination, ‘Figure 1’.
3. Technological strategy at material level
Building is viewed as a reservoir of materials known as Building As Material Bank (BAMB), at the end of their service many buildings end up demolishing, resulting in a large amount of demolition waste and creating negative impact on the ecosystem and causing the depletion of natural resources. Materials resulting from demolition are either worthless considered waste or carry a certain value and therefor are recycled, so the greater the value that a material owns means less waste, this represents the basic notion of BAMB which is to create methods and strategies to preserve the value of building materials over time by creating flexible dynamic design methods. Instead of disposing of building materials at the end of the building's life, their value is preserved in the building (the bank) as a future balance for use in another building. This slows down the depletion of resources and reduces waste [6].

4. Recycled material in architecture
Recycled material refers to the material that has undergone reprocessing / recycling before starting another use. Reprocessing usually entails transportation and energy consumption, which explains why reuse is considered better than recycling [7]. It is also defined as materials that have been reprocessed from reclaimed materials by the manufacturing process and converted into a final product or component for inclusion in a product, as for reclaimed material is considered as the material that could be disposed of as waste or used to recover energy, but instead it was collected and recovered as materials for other inputs, instead of new raw materials for recycling process, reused material is a reclaimed material that has not undergone any additional steps in the manufacturing process before it is used again [8] and recyclable material is the material that can be separated from waste and sent to the recycling facility for recycling [7]. Therefore, recycled material is an obtained material from the recycling process, it may be in form of a new product and contains in its composition a percentage of recycled components or a product that is reused for the same previous functional purpose or for another functional purpose, and so recycled material includes the following:
- New-form materials manufactured of recycled components from other materials in a certain amount of proportions, whether these components have previous structural origins such as rubble or other wastes.
- Reclaimed / Salvaged items from previous buildings or other sources.

5. Concrete recycling technology
There are several concrete waste treatment stages as shown in ‘Figure 2’ and the ability to extract usable recycled concrete aggregate (RCA) in new concrete mix that sometimes overcomes natural aggregate specifications; one of the first concrete recycling stages is represented by using concrete crushers ‘Figure 3’ and there are many types, but the resulted aggregate by this method has low quality and is only suitable as filling or for road sub bases mixture. As for other treatment methods that count
on heating process, the RCA is of high quality, the main challenge lies on separating maximum cement paste from natural aggregate (NA) (the basic concrete aggregate components), hereby a brief about each recycling treatment:

5.1 Heating and rubbing
Concrete is heated up after the demolition process to approximately 300°C, so the cement paste becomes brittle due to drying. The hot concrete is rubbed with a grinder to separate the cement paste from the aggregate surface. The degree of rubbing varies according to the rotation speed of the grinder [9]. According to Akbarnezhad et al. (2011) heated concrete at temperature between 300°C to 500°C create heat and mechanical pressure due to rubbing effect on RCA particle. In a vertical kiln, concrete rubble is heated to dry the cement paste and to remove mortar, the heated concrete debris is fed into the rubbing mills with steel balls, and then by a sorting system the concrete aggregate is emptied and separated. The inventors of this method claim that it can increase the RCA quality of compliance with JCI's (Japan Concrete Institute) standards for high quality RCA [10] ‘Figure 4’.

5.2 Microwave heating and rubbing
Recycling concrete by microwave heating is a completely new technology as shown in ‘Figure 5’. Additives such as pozzolanic materials improve the chemical bonding and mechanical friction between the original coarse aggregate surface coating layer (OCA) and cement arrays in the interfacial
transition zone, which is the weak part of the concrete. Hence, recycled coarse aggregate can be recovered from concrete structures and to improve mechanical performance of concrete, this technique includes encapsulating the original coarse aggregate with iron oxide (Fe2O₃), which contains high dielectric constant; the aggregate surface is heated and weakened by microwave selectively to manufacture the RCA. This technology allows to almost completely recycling aggregate by recovering high quality RCA and using small amount of energy it also allows a trade-off between improvement in concrete strength and overall recovery rate [11].

5.3 Advanced dry recovery

The process of separating fine materials from RCA which are named (fines) with a diameter size of 0-1 mm is necessary, as fines contain cement paste or mortar that increases the need for water when mixing and makes the fines mixture sticky. It is possible that sulfate compounds and chlorides presences in fines are included that result in making production difficult. In the processing of concrete aggregate, attention is needed to the issue of cement adhesion to the surface of coarse fraction.

ADR is considered as a low-cost mechanical process that can be applied to moist materials without prior-drying or wet sieving. ‘Figure 6’ and ‘Figure 7’ illustrate the principle of ADR process, the process is fed with concrete waste selected from demolition processes and crushed down into concrete fracture with a diameter of less than 21 mm; autogenously milling is applied to remove the loose slurry from the aggregate surface. First, kinetic energy is utilized to break the water bond that is created by surface moisture related to fine particles, after that fines less than 1 mm are removed, then coarse aggregates with 4-12 mm diameter, and superfine fragment with diameter 1-4 mm are separated from the impurities such as wood, plastics and foams.

Coarse aggregate, which usually accounted for approximately 50 percent of the volume of recycled aggregate, demonstrated properties comparable to natural aggregate NA in terms of operability and compressive strength. ADR achieves the highest environmental benefit through recycling on or near site, therefore recycled aggregates are recommended for local application [12].
5.4 Heating air classification system
HAS is a new technology type that applies heating and separation processes simultaneously inside a fluidized bed-like chamber under controlled temperatures reaching ± 600°C and curing time takes between 25-40 seconds. In this process, moisture and contaminants are removed from end of life fine concrete aggregate 0-4 mm, resulting in enhanced superfine recycled concrete particles < 0.125 mm, which are mainly consisted of hydrated cement, thus adding value to ultrafine end of life concrete fragments [13] ‘Figure 8’, ‘Figure 9’.

Figure 8. Heating air classification system.  
Figure 9. HAS processing unit on Hoorn site in Netheland.

‘Figure 10’ illustrates recycling concrete strategies with the methods mentioned above.

Figure 10. A suggestion for recycling concrete technological strategies.

6. Benefits from recycled concrete
Quarrying, crushing and grinding natural aggregate creates greater environmental burden than crushing and recycling concrete, especially with regard to carbon dioxide. This is possibly due to the fact that, in all natural aggregate production processes, the energy consumption involved in the extraction processes must also be taken into account [22]. There are many benefits to recycling concrete instead of throwing it or burying it in landfills [11]:

- Saving space by keeping rubble and concrete debris away from landfills.
- Use of recycled materials as an alternative to aggregates reduces the need for pebbles excavation.
- Recycling one ton of cement saves 1,360 gallons of water and 900 kg of CO2.
- Use of recycled concrete as a base layer for roads reduces pollution resulting from trucking materials.

7. Application Examples of recycled concrete in architecture
Lendager Group designed a residential development project in Copenhagen named Upcycle Studios, they used recycled materials to build 20 residences, employing recycled concrete, recycled double glass and reclaimed floorboards, [29] ‘Figure 11’.

![Figure 11. Upcycle Studios project.](image)

SOS Children's Villages Lavezzorio Community Center project is located in Chicago, USA, designed by Studio Gang Architects and was completed in 2008: the large external wall reflects the shape of layers constructed from a diverse mixture of recycled concrete poured into wavy horizontal layers. The layers express the successive phases of concrete pouring and the fluid nature of the material, and suggest the notion of geological layers, [30] ‘Figure 12’.
8. Issues of existing concrete blocks in Iraq
Concrete blocks are considered one of the components of construction and demolition waste C&DW, according to the Central Bureau of Statistics. Table 1 shows the amount of building rubble in Iraq in tons for the years 2015, 2016 and 2017.

| Year | Rubble amount (tonnes/year) |
|------|-----------------------------|
| 2015* | 2,228,909                   |
| 2016* | 4,753,766.3                 |
| 2017  | 11,063,323.5                |

*Except for Mosul and Anbar provinces

Volume of demolition rubble is greater than the actual construction volume of concrete and bricks [24]. United Nations Environment Programme UNEP, (2017) explained that conflicts in urban environments, as in cities such as Mosul and Ramadi, pose long-term environmental health risks. Millions tons of debris and rubble resulting from the destruction of residential and commercial areas present a major challenge to cleaning, and this includes mixed forms of solid and hazardous waste. When explosive weapons hit buildings and facilities, they scattered blocks of various materials, including concrete, cement, and sometimes asbestos. This can lead to environmental pollution and pose threat to human health. The cost of transporting 10 million tons of Mosul waste alone is estimated at 250 million US dollars [25], ‘Figure 13’, ‘Figure 14’. It is known that rubble, especially in conflict affected areas in Iraq, contains a range of waste and materials that can harm humans, plants and animals, and the surrounding environment. Therefore, from this standpoint, these risks should be taken into account when developing and adopting operational procedures for any recycling rubble site. These wastes and materials ‘Figure 15’, ‘Figure 16’ include the following [26]:
- Explosive devices and unexploded ordnance.
- Hazardous wastes, such as oils, greases, and solvents from industrial sites.
- Corps.
- Chemicals, pesticides, and chemical warfare agents such as yperite, mustard gas and explosives.
- Heavy metals produced by the structural elements of destroyed building / facility.
- Medical waste from hospitals and health care centers.

Figure 13. Limited rubble crushing in Almazen site in Mosul with the support of International Organisation of Migration.

Figure 14. Manual rubble sorting in Iraq, including the removal of non-recyclable waste, such as plastic materials, furniture, and others.

Figure 15. Debris issue in Iraq.

Figure 16. Unexploded ordnance in rubble, Iraq.

Concrete block barriers that were used for security purposes also constitute of large amount of concrete that must be considered as a source that may need to be recycled once reaching their end of life, ‘Figure 17’. Hassan, (2014) indicated the possibility of recycling construction waste and reused it as aggregate in concrete mixtures within the Iraqi and American standard specifications. It is also possible to manufacture non-bearing concrete blocks such as ones used in construction, especially in structural buildings and manufacturing of concrete blocks for street pavements such as shtiker (flags) and muqarnas (pavement bricks) according to IQS and use recycled concrete in casting floors, walkways, sewage works and low bearing bases [27], Salah Sabbar explained that the percentage of concrete and gravel in the rubble is 38.34% in Anbar Governorate. He also believes that the production of materials from rubble is cheaper than natural materials, and the cost of crushing 1 m³ of rubble was estimated at 1.25 USD, which is cheaper than the value of 1 m³ of natural materials from quarries, which is estimated at 1.67 USD [28].
Figure 17. Concrete block barriers issue in Iraq.
Table 2 provides an analysis of the different concrete recycling methods, indicating the pros and cons of each method.

**Table 2. Analysing concrete recycling methods.**

| Recycling methods   | Advantages                                                                 | Disadvantages                                                                 | Outcome of recycling concrete                                                                 |
|---------------------|-----------------------------------------------------------------------------|-------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|
| Mechanical crushing | 1- Low cost and can be used in developing countries [14].<br> 2- Crusher can be installed on site, thus avoiding pollution and transportation costs. As for the use of large fixed crushers outside the site, transportation is needed.<br> 3- Applicable in Iraq.<br> 4- Input material size varies from 40 to 300 mm<br> 5- Production capacity is 90 tons / day for small crusher, 300 tons / day for medium crusher and 720 tons / day for large crusher [19]. | 1- Generation of fine powder during crushing [11].<br> 2- Crushing produces noise levels, atmospheric pollution and potential water pollution [14].<br> 3- Failure of removing non-concrete materials prior to recycling affects negatively on the recycled aggregate properties [15]. | Produce low-quality, coarse recycled concrete aggregate up to 75 mm which is not suitable in new concrete mixes, but rather used in sub base layer and foundation layers for roads, and is added in small proportions up to 20% [15]. |
| Heating and rubbing | 1- Recycled aggregate is used as a raw material in ready-mix concrete; the resulting fine powder from cement paste is rotated and used as a raw material in cement manufacturing and cement mixes or soil stabilizer; it reduces CO2 emissions, especially if fine powder is used in the cement industry [9].<br> 2- Operate on site and do not require water; the material input size into processing is ≤50 mm [18] | 1- Microwaving is considered more efficient than heat treatment in terms of separating the mortar from the concrete aggregate by 30% [10].<br> 2- Fuel consumption for heating purpose and electricity scrubbing process; production capacity is 10 tons / hour [9].<br> 3- High temperature up to 300˚C [18]. | 1- Recycling process results in high quality coarse aggregate and cement mortar. RCA can be used as a complete substitute for natural aggregate in concrete mixture and give similar or better properties of natural aggregate [16].<br> 2- The proportion of coarse recycled aggregate represents 35% coarse, 30% fine, and 35% very fine (powder) [18]. |
| Microwave heating & rubbing | 1- This technology allows for nearly complete recycling of aggregates through recovery of high-quality RCA with energy savings; there is a trade-off between improving concrete strength and the overall aggregate recovery rate [11].<br> 2- Precise electronic control and clean heating processes without generating any secondary pollutants; short processing time; fast heating rate [14], and as low as 140˚C [18].<br> 3- A technology considered to be the least polluting towards environment, and does not need water [18]. | 1- Input material size is relatively small ≤ 30 mm [18].<br> 2- Low production capacity of 0.65 tons / hour [18]. | Obtaining high quality RCA [18]: 51% coarse can be a substitute for natural aggregate 30% fine 35% very fine (powder) |
| Advanced dry recovery | 1- Used for sorting clean coarse aggregate; a mobile mechanical technology where concrete is processed and recycled at demolition sites or near concrete feeding plants, thus reducing the intensity of transport related to construction activities; using kinetic energy to break the water bond formed by moisture of fine particles; energy efficient, and the process does not require water; the ability to classify aggregates independently from their moisture content [17].<br> 2- Maximize the environmental benefit if used in close site proximity; it is considered low cost [12].<br> 3- Large production capacity up to 60 tons / hour [20]. | Input material size is small ≤ 12 mm [17]. | Crushed aggregates are of different sizes (coarse and fine) and of good quality that can substitute natural aggregate; Concrete made of 4mm recycled coarse aggregate has compressive strength similar to natural aggregate, and in some cases has better performance. [20] |
| Heating air classification system | 1- Used to produce clean, fine aggregate by heating and separating very fine, wet cement components; a mobile technology where concrete is processed and recycled at demolition sites or near concrete feeding plants, which reduces the traffic intensity of construction activities [17].<br> 2- The process does not need water.<br> 3- Heating temperatures varies 105˚/ 400˚/ 500˚/ 600˚/ 750˚C [21]. | 1- It is considered as a complementary technology to ADR; using diesel fuel, i.e. non-renewable energy, to generate hot gas [17].<br> 2- Low production capacity 3 tons / hour [13]. | It results in high-quality fine aggregates that are used as a cementing agent in new cement to reduce the cement content by up to 5% [13]. |
9. Analysis
It is clear that all treatment processes based on heat factor do not need water and have an effective recycling quality to produce suitable RCA to apply in new concrete mixtures and have competitive quality or in some cases better quality than natural aggregate, so accordingly the research review an ascending order of recycling techniques, starting from the least efficient to the most efficient:
Thus it was found that although the recycling heating and rubbing technique allows the size of the input material up to 50 mm compared with the size of the material by the microwave heating and rubbing method, it needs a high heating level and that the proportion of recycled aggregate replacing natural aggregates is only 35% of the concrete volume aggregate used for recycling, so we will consider this technology to be fourth in order. Coming in the third place is recycling technology by microwave heating and rubbing, as it is considered the least polluting to the environment and the heating level reaches 140˚C, i.e. less heat than the previous one, but it has relatively little efficiency because it requires advanced technology compared to other methods, its production capacity is less than other techniques and the size of the input material for the recycling process is smaller when compared with the heating and rubbing process. HAS comes in second place as it is a system that relies on ADR process, but its output is represented by high-quality fine aggregate that can be used as supplementary material in the cement industry, and finally the ADR comes in first place as it is a relatively uncomplicated process compared to its predecessors, its output of coarse recycled concrete aggregate is an alternative and sometimes better than natural aggregate, it has higher production capacity and represents the basic step to HAS technology. It is also considered low cost and achieves the highest environmental benefit if used near the site.

Given the fact that Iraqi reality is burdened with concrete waste as a result of many factors and circumstances, it was necessary to consider its recycling to achieve environmental and economic benefits, and taking in consideration time factor as concrete waste quantities are undeniable, so an efficient, effective and fast treatment strategy must be proposed, and based on the review of the most important concrete recycling techniques, the research suggests adopting the advanced dry recovery method ADR because:
- It addresses the Iraqi issue in terms of high production capacity and being a relatively simple technology, so it will contribute to a rapid concrete recycling as the time factor is crucial, especially since the amount of concrete waste in Iraq is large.
- No water is needed and is a low cost technology.
- Its output of coarse recycled concrete aggregate can be a substitute for natural aggregate in new concrete mixes, so it will contribute to preserving natural resources, and it will be an important part of the urban boom in the country.
- ADR outputs are considered inputs to HAS, so it is possible to obtain maximum benefit possible if need arises.

The research develops an analytical table 3 and table 4 according to analysis based on strengths, weaknesses, opportunities, and threats (SWOT) method to draw final conclusions.
**Table 3. SWOT analysis for concrete recycling technological strategies.**

| POSITIVE | NEGATIVE |
|----------|----------|
| **Strengths** | **Weaknesses** |
| 1. Concrete recycling process saves the environment from non-degradable concrete waste burden. | 7. Recycling process results in fuel consumption. |
| 2. As a result of recycling process, recycled concrete aggregate can be used as an alternative to natural aggregate, so the recycling process contributes to preserving quarries and reducing risks of depleting natural resources. | 8. The production capacity of recycled concrete aggregate is less than the production capacity of extracting natural aggregate from quarries. |
| 3. Concrete recycling waste saves land area. | 9. Recycling is still not activated in many countries, especially developing countries. |
| 4. Heating-based treatment methods do not require water. | 10. Lack of awareness of the importance of recycling and the positive results it reflects on the environmental and economic levels. |
| 5. Concrete recycling based on heating factor is considered to be less polluting to the environment in terms of CO2 emissions when compared to cement manufacturing process. | 11. Sorting complexity of concrete waste away from other materials as demolition operations is still taking place in an unplanned or practical way. |
| 6. The ability to recycle concrete on site and reduce transportation use. | 12. Rapid demolitions are still preferable for being faster and easier. |
| **Opportunities** | **Threats** |
| 14. Recycling provides more job opportunities. | 18. The inability to use low-quality recycled aggregates in new concrete mixes. |
| 15. Recycling processes can produce materials that are more efficient and effective than raw materials. | 19. It is difficult to predict concrete durability that is composed of recycled aggregates, as it is relatively still a recent application. |
| 16. Recycling process is economical if it is done on site and using existing concrete waste. | 20. Recycled concrete aggregate might be difficult to recycle again. |
| 17. Encouraging innovation among engineers to employ recycled concrete aggregates in various fields. | 21. Necessity for recycled aggregates to comply with standards test to ensure that it is strong and durable enough for use in construction. |
| 13. The inability to use low-quality recycled concrete aggregate might be difficult to recycle again. | 22. Complying difficulty with standard tender requirements terms, because meeting the standard is necessary to reassure the project owner about the quality and credibility. |
| 23. Lack of an acceptable holistic approach till today that delivers high quality recycled concrete aggregate in economically and environmentally attractive conditions. | 23. Lack of an acceptable holistic approach till today that delivers high quality recycled concrete aggregate in economically and environmentally attractive conditions. |
Table 4. SWOT analysis for concrete recycling technological strategies in Iraq.

| POSITIVE | NEGATIVE |
|----------|----------|
| **Strengths** | **Weaknesses** |
| 24. The amount of concrete waste in Iraq is massive that it becomes a fertile base for adopting a strategy for recycling it. | 29. Recycled concrete aggregate specifications produced in Iraq are not suitable to be used in new concrete mixtures. |
| 25. Saving land areas that are reduced due to concrete waste. | 30. No recycling strategy has been employed yet, to produce high quality concrete aggregate. |
| 26. Iraq began to recycle concrete by mechanical crushing. | 31. Demolition operations is still unorganized up to the level to facilitate concrete sorting of blocks and materials for recycling. |
| 27. Producing materials from concrete rubble is cheaper than extracting natural materials. | 32. Large quantities of accumulated concrete waste are contaminated by major factors such as wars, which increase the challenges of its recycling process. |
| 28. In Iraq, recycled concrete aggregate is used as a sub base layer for roads and in the production of non-bearing concrete blocks. | |

| **Opportunities** | **Threats** |
|-------------------|-------------|
| 33. Concrete recycling can provide more job opportunities locally. | 38. Difficulty to predict the longevity of concrete consisting of recycled aggregates, as it is relatively still a recent application. |
| 34. Raise awareness among engineers and those in the construction sector about the importance of adopting recycled concrete aggregates in their projects. | 39. Contamination of rubble and concrete waste with substances that may be harmful to human health. |
| 35. Recycling concrete can mitigate concrete waste issue, as it represents approximately third of the amount of building debris in Iraq. | |
| 36. Supporting innovation among engineers to employ recycled concrete aggregate in various fields. | |
| 37. The possibility of applying the ADR strategy for recycling concrete, as it is the best alternative for Iraq due to its low cost and large production capacity, which makes it time saving. | |

10. Conclusion

- The amount and volume of concrete waste in Iraq calls for urgent need to adopt an efficient strategy to recycle them, as they are significant quantities, as well as being the largest proportion of construction debris.
- Sources of concrete waste in Iraq comes from demolition, rehabilitation, or conflicts in some governorates.
- Despite the multiplicity of concrete recycling strategies, their applications and use in Iraq are still in an early stage.
- Application of recycled concrete aggregate in Iraq are still limited to its use as a sub base layer for roads, despite the possibility of producing high quality concrete aggregates that allow it to be used in new concrete mixes.
Within the available strategies for recycling concrete, it is important to spread and raise awareness among workers and those in the construction sector in Iraq of the necessity for adopting recycled concrete aggregates as a material in their projects.

It is suggested to apply ADR as a concrete recycling strategy in Iraq, as it is low cost and has a high production capacity and thus is economical in the time factor.

Concrete recycling methods that rely on heat factor have less need for water during the recycling process, which encourages its use.

Recycling concrete in situ and using recycled concrete aggregates is an environmentally sustainable process, as it is considered cheaper than natural aggregate and can achieve higher efficiency in new concrete mixtures.

Various specifications of recycled concrete aggregate made it difficult to comply with the standard required within contractual terms, to reassure the project owner about the quality and reliability.

References
[1] Adler P S 1989, Technology strategy: A guide to the literature, Research on Technological Innovation, Management and Policy vol 4 pp. 25-151
[2] Du Preez N, Schute C S and Katz B R 2013, The Relationship between Innovation and Technology Strategy, International Conference on Competitive Manufacturing
[3] Birnbaum W, Andrew R and Philip H 1989, Technological Infrastructure and the Implementation of Technological Strategies, Management Science vol 35 p.1014
[4] Ivan M, Antony T, Rami B and Judith A S 2013, Aligning Enterprise System and Software Architectures, Gamon, Joel, United States of America, Business Science Reference p 17
[5] Pourkhamami P, OSibyond [Online] https://www.osibeyond.com/resources/technology-strategy-101/ [Accessed 26 October 2020]
[6] Capelle T 2019, Building As Material Bank Testing BAMB results through prototyping and pilot projects
[7] Bergman D 2012, Sustainable Design: A Critical Guide, Princeton Architectural Press p 105-106
[8] 2014 Recycled Claim Standard Implementation Manual, Textile Exchange.
[9] Shima H, Tateyashiki H, Matsuhashi R and Yoshida Y 2005, An advanced concrete recycling technology and its applicability assessment through input-output analysis, Journal of advanced concrete technology vol 3 pp. 53-67
[10] Akbarnezhad A, Ong K, Zhang M H, Tam C T and Foo T WJ 2011, Microwave-assisted beneficiation of recycled concrete aggregates, Construction and Building Materials vol 25 3469–3479
[11] Choi H, Lim M, Choi H, Kitagaki R and Noguchi T 2014, Using Microwave Heating to Completely Recycle Concrete, Journal of Environmental Protection vol 5 pp. 583-596.
[12] Wahlström M, Bergmans J, Teittinen T, Bachér J, Smeets A and Paduart A 2020, Construction and Demolition Waste:challenges and opportunities in a circular economy, Eionet Report
[13] Moreno-Juez J, Inigo J V, Abraham T G, García-Cortes V and Di Maio F 2020, Treatment of end-of-life concrete in an innovative heating-air classification system for circular cement-based products, Journal of Cleaner Production vol 263 121515

[14] Al-Laham L 2017, Master Thesis Abstract: The technique of reusing concrete resulting from demolishing buildings, Syria - Damascus: Syrian Virtual University

[15] Akbarnezhad A 2010, A thesis submitted for the degree of doctor of philosophy: Microwave-Assisted Production of Aggregates from Demolition Debris, Singapore: National University of Singapore.

[16] Kalinowska K, Pawluczuk E and Boltryk M 2020, Waste-free technology for recycling concrete rubble, Construction and Building Materials vol 234 117407

[17] Gebremariam A T, Di Maio F, Vahidi A and Rem P 2020, Innovative technologies for recycling End-Of-Life concrete waste in the built environment, Resources Conservation & Recycling vol 163 104911

[18] Quattrone M, Angulo S C and John V M 2014, Energy and CO2 from high performance recycled aggregate production, Resources Conservation and Recycling vol 90 pp. 21-33

[19] United Nations Environment Programme UNEP 2018, Mosul Debris Management Assessment, United Nations Environment Programme

[20] Lotfi S, Deja J, Rem P, Mróz R, Roekel E and Der Stelt H 2014, Mechanical recycling of EOL concrete into high-grade aggregates, Resources Conservation and Recycling vol 87 pp. 117–125

[21] Lotfi S and Rem P 2016, Recycling of End of Life Concrete Fines into Hardened Cement and Clean Sand, Journal of Environmental Protection vol 7 pp. 934-950

[22] Estévez B, Aguado A and Josa A, Environmental Impact of Concrete Recycling Coming from Construction and Demolition Waste (C&DW)

[23] Obaid M K, Abdul Rahman I, Idan I J and Nagapan S 2019, Construction Waste and its Distribution in Iraq: An Ample Review, Indian Journal of Science and Technology vol 12(17)

[24] Nsaif B, Abd A M and Hameed A H 2020, Development BIM Model to Manage the Demolition Waste in Iraqi Construction Projects, Diyala Journal of Engineering Sciences vol 13 pp. 93-98

[25] Helpdesk Report 2018, Environmental risks in Iraq, UK: Department for International Development

[26] Iraqi Ministry of Health and Environment 2020, Guidelines for environmental management of rubble recycling sites, United Nations Environment Program

[27] Hassan A Q 2014, Estimating and recycling construction waste in Basra Governorate, Basra Journal of Engineering Sciences vol 14 pp. 136-143

[28] Sabbar S, Studying the properties of the debris and their use in paving layers of roads and concrete construction
[29] https://www.dezeen.com/2019/04/16/upcycle-studios-townhouses-lendager-group-copenhagen-recycled-materials [Accessed 20 April 2021]

[30] https://www.archdaily.com/28636/sos-children%25e2%2580%2599s-villages-lavezzorio-community-center-studio-gang-architects [Accessed 20 April 2021]

[31] https://www.unep.org/ar/alakhbar-walqss/algst/alraq-mshrw-laadt-tdwy-alanqad-ysy-ltzyz-wdt-alnazhyn-wst-tzayd-mkhatr-tfshy [Accessed 16 March 2021]