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Review

Design Strategy for Recycled Aggregate Concrete: A Review of Status and Future Perspectives

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Citation: Makul, N.; Fediuk, R.; Amran, M.; Zeyad, A.M.; Klyuev, S.; Chulkova, I.; Ozbakkaloglu, T.; Vatin, N.; Karelina, M.; Azevedo, A. Design Strategy for Recycled Aggregate Concrete: A Review of Status and Future Perspectives. *Crystals* **2021**, *11*, 695. https://doi.org/10.3390/cryst11060695

Academic Editor: Ing. José L. García

Received: 19 May 2021
Accepted: 15 June 2021
Published: 17 June 2021

Abstract: Currently, a number of disadvantages hampers the use of recycled concrete aggregates (RCA). The current review proves that concretes made with complete replacement of natural aggregate with RCA allow the production of high-quality concrete. One of the possibilities for improving concrete properties with RCA is the use of extended curing and pozzolanic materials with varying cement ratios. The potential use of RCA concretes is in the production of high-value materials that increase environmental and financial benefits. RCA have strong potential in the development of a new generation of concrete and stimulate economic activity in many countries in addition to optimizing natural resources. Economic benefits include minimal travel costs; cheaper sources of concrete than newly mined aggregates; reduction of the landfill area required for the placement of concrete waste; the use of RCA minimizes the need for gravel extraction, etc. The proposed strategy could be to sequentially separate demolition waste such as roof finishes, waterproof materials, interior and exterior materials, etc. Closing life cycles is the main approach used for efficient structures for the recycling and reuse of construction and demolition waste in the production and recovery of materials, especially when recycling and reusing materials. In the life cycle, the recycling of recovered materials allows them to be used for new construction purposes, avoiding the use of natural concrete aggregates. Government, design institutes, construction departments and project managers should be involved in the creation and use of RCA. In demolition and construction, the main players are the project owners. Their obligations, expectations and responsibilities must be properly aligned. For the past 20 years, recycled concrete aggregate from demolition and construction waste has been considered as an alternative to pure concrete in structural concrete to minimize the environmental impact of construction waste and demolition waste and the conversion of natural aggregate resources. It is now recognized that the use of RCA for the generations of concrete is a promising and very attractive technology for reducing the environmental impact of the construction sector and conserving natural resources. In the market, the selling price is not an obstacle for market applications of RCA, as there are scenarios in which their cost is lower than the cost of products made from conventional building materials. This is more of an acceptance factor in the market for recycled concrete aggregates. In this sector, the lack of identification, accreditation and uniform quality certification systems and their narrow application cause some marketing problems. With proper RCA preparation, concrete with standard physical and mechanical properties and performance characteristics can be obtained.

Keywords: ecological impacts; costs; life cycle assessments; quality performance; optimum concretes; sustainable concrete selection

1. Introduction

The construction sector has been growing considerably in recent decades as a result of global urban development. In general, the increase in the urban area contributed to the increase in the global demand for concrete, and concrete production reached 48.3 billion tons in 2015 [1]. The production of concrete has negative impacts on the environment due to its dependence on cement, which is one of industry's main sources of carbon dioxide, in addition to its consumption of natural sources of raw materials and rocks to produce fine and coarse aggregates [2]. Cement production and aggregate preparation consume non-renewable fossil energy, and carbon dioxide production is the main cause of global warming [3,4] (Figure 1).

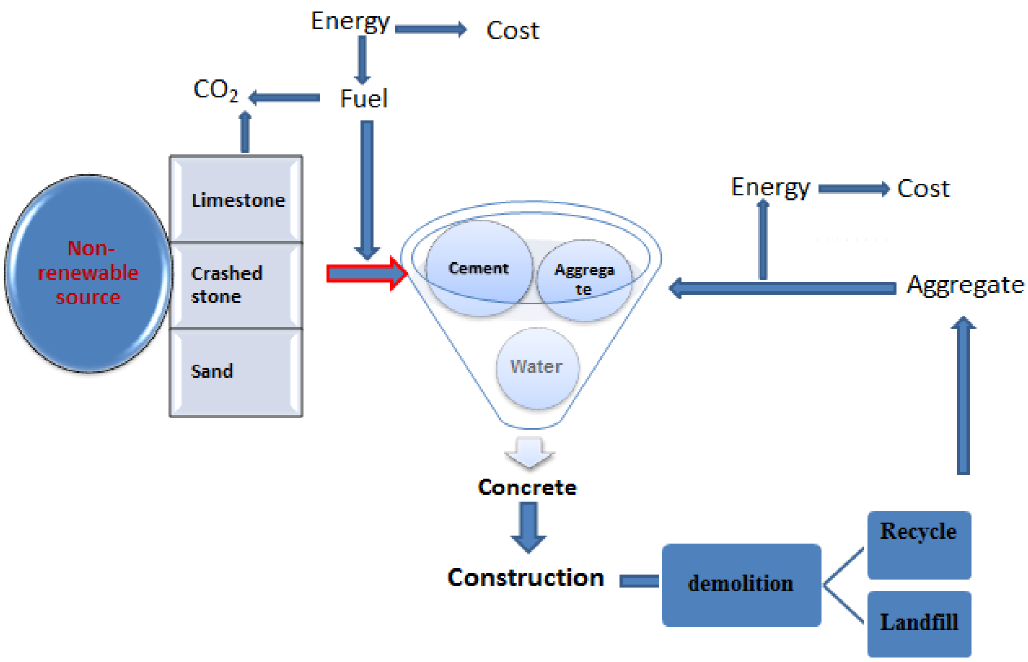
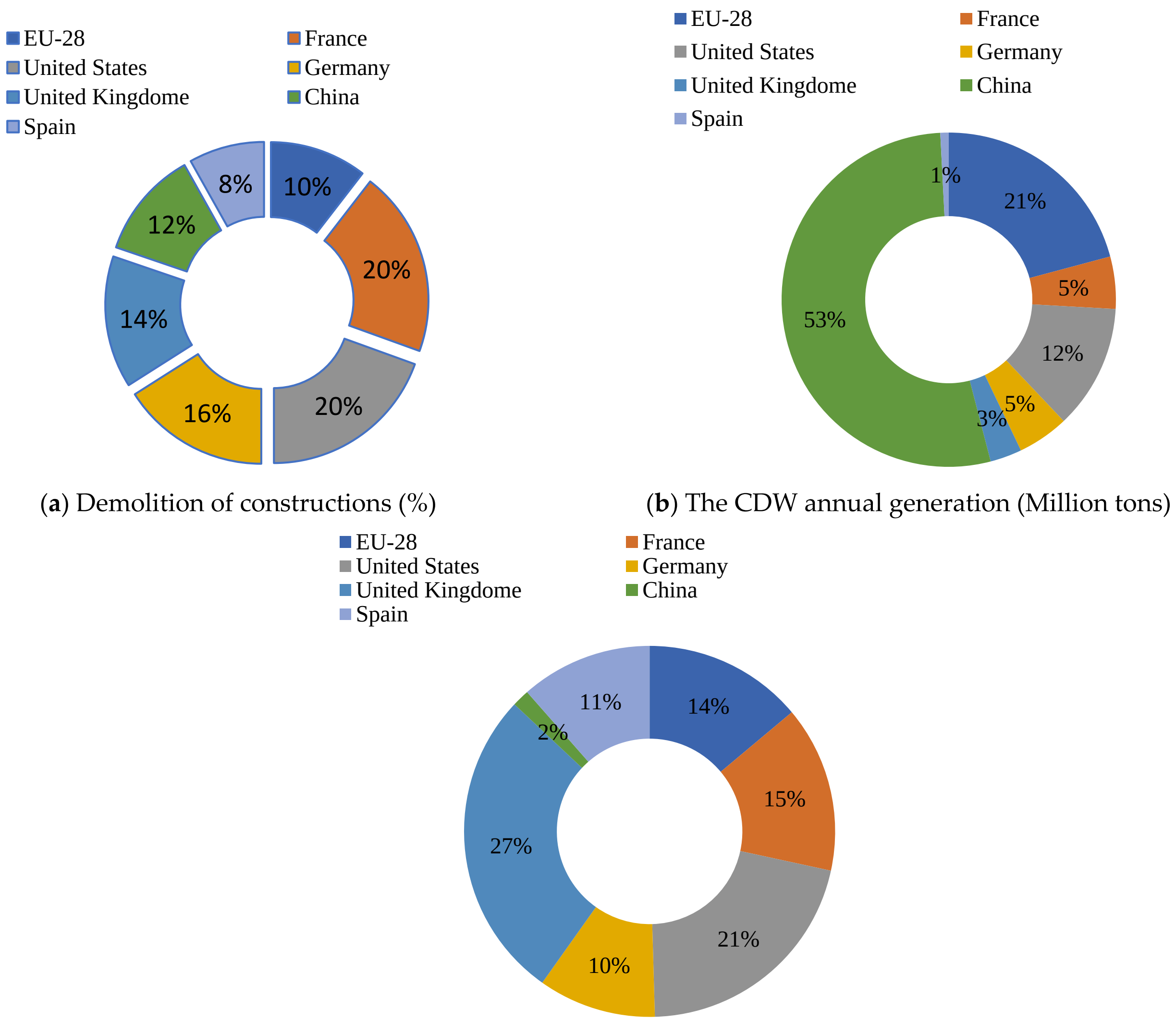


Figure 1. Renewable cycle of recycled concrete aggregates (RCAs).

The production of concrete requires the consumption of huge quantities of aggregates, as the global consumption of aggregate associated with construction was about 40 billion tons in 2014 [5]. The demand for aggregates is expected to double in the coming decades if the high demand for concrete persists. Consequently, the consumption of natural aggregate sources will be increased. On the other hand, there is the problem of demolishing old buildings or the need for urban development.

Demolition causes large amounts of construction and demolition waste to be generated around the world, having an increasingly negative effect on the environment. Construction and demolition waste (CDW) is the largest waste stream worldwide, ranging between (30–40% of total solid waste) [6,7]. The European Union produces the equivalent of 36% of the total solid waste produced in 2016, at a rate of 924 million tons, while the United States produces approximately 67% of the amount of 534 million tons, and China has produced a proportion of between 30 and 40%, by 2.36 billion tons in 2016 [8–10]. Figure 2 shows demolition of constructions and recycling of waste globally.



(**a**) Demolition of constructions (%)

(**b**) The CDW annual generation (Million tons)

(**c**) The CDW recovery status (%)

Figure 2. Demolition of constructions and recycling of waste globally.

Sustainability in the construction industry is an important matter that focuses on preserving natural resources that are crucial to the continuation of urban growth, in addition to reducing carbon emissions and saving the environment. There is ongoing research to reduce the depletion of natural resources by reducing their consumption or finding an alternative, and therefore it is necessary to take into account sustainability during urban planning for various projects and develop strategies for that.

Accordingly, scientists have recommended finding alternative methods for the purpose of reducing the negative environmental impacts of concrete through the following ways: (i) reducing cement consumption through the use of cementations materials or complementary material [11,12]; (ii) reducing dependence on cement concrete by finding concrete that does not depend on cement (geopolymer concrete) [13–19]; (iii) reducing dependence on natural sources of aggregates through the use of recycled aggregates (construction demolition waste) [20–22]. Research related to the development of alternative concretes, which apply raw material from solid waste or production processes, is widely studied, mainly from the perspective of the life cycle and quality performance. A major challenge is in the establishment of a complete study involving relations between the mixture and its optimization process, for concrete in the fresh and hardened state [23,24]. The evaluation of the necessary characteristics of each type of concrete depends on its application, aiming at the development of an optimal concrete mix (OCM), which meets the technological and economic properties. As an example, the concrete needed to build a building with several floors is obviously different from that needed to build a one-floor residence. The determination of the optimal mixture must be based on multiple parameters, which include technological, cost and environmental issues [25,26]. Therefore, the best mix of concrete for a given application, must take into account multiple factors, and one of the points that is currently being discussed is the application of alternative materials, such as the use and aggregates from recycled concrete. This contributes to the reduction of environmental impacts related to the destination of this solid waste and CO_2 emissions into the atmosphere. An observation that should be highlighted in the development of concretes that use unconventional materials is its durability regarding the exposure of the structure, which must have a useful life compatible with the traditional concrete [27,28]. Certainly, the financial issue is one of those that most limit the development of alternative construction materials. These new materials must be designed in order to be cost competitive with conventional materials ones, as is the case with concrete using fly ash [29]. A limiting factor related to the cost of alternative concretes is that the application of alternative supplementary materials may promote the need to increase cross sections in some structural components of concrete, increasing the final costs of this material [30,31]. Thus, the complete planning of concrete mixtures becomes mandatory, taking into account the variables related to their use and the respective applications [32,33]. Non-alternative materials applied to concrete, such as recycled aggregates, are only eco-friendly if their destination is an environmental problem, otherwise they threaten the useful life and final quality of the concrete The dosage of concretes using recycled materials must be optimized, in order to provide better properties and enhance the sustainability of these new materials [34,35]. The vast majority of literature reviews have shown individual effects of different properties on recovered concretes, but there is a shortcoming in research that associates multiple combined effects of the use of recycled aggregates in the development. Another limitation of the existing literature is the use of high rates of integration of aggregates in recycled concretes, limiting the analysis from a single perspective.

A more acceptable way of reducing costs is the use of inputs close to the production site, in addition to the application of innovative materials from the technological point of view. An example is the application of RCA and laterites mixed with fine aggregates for concrete. In this research, the authors recommended a new approach aimed at overcoming problems of selection and mixing of the optimal concrete, taking into account the costs, performance, quality and sustainability [20,36]. Currently, research using different amounts of recovered concrete aggregates has been promoted, in order to improve the result and its application. This research deals with methods of optimization of concrete mixtures produced with RCAs, aiming at minimizing costs, meeting structural and performance parameters according to their application and environmental factors [20,37]. Figure 3 presents the principles of designing a strategy for RCAs.

This approach has supported sustainability measures in concrete materials. Although a number of authors have contributed to the environmental impact study and assessment of RAC (recycled aggregate concrete), there are still some problems, including the development of a clear concrete sustainability strategy based on recycling of the building demolition waste. Therefore, this paper outlines a strategy for achieving sustainability in the field of concrete production. According to a corresponding literature review, this paper adopts a strategy based on the following elements: vision, mission and guiding principles of RCA, technical and social development for RCA, economic development for RCA, sector performance for RCA, medium term strategy: maintaining stability and sustaining growth of RCA, macroeconomic management of the utilization of RCA, restructuring the public and private sectors to the utilization of RCA, social development of the utilization of RCA, economic development of the utilization of RCA.

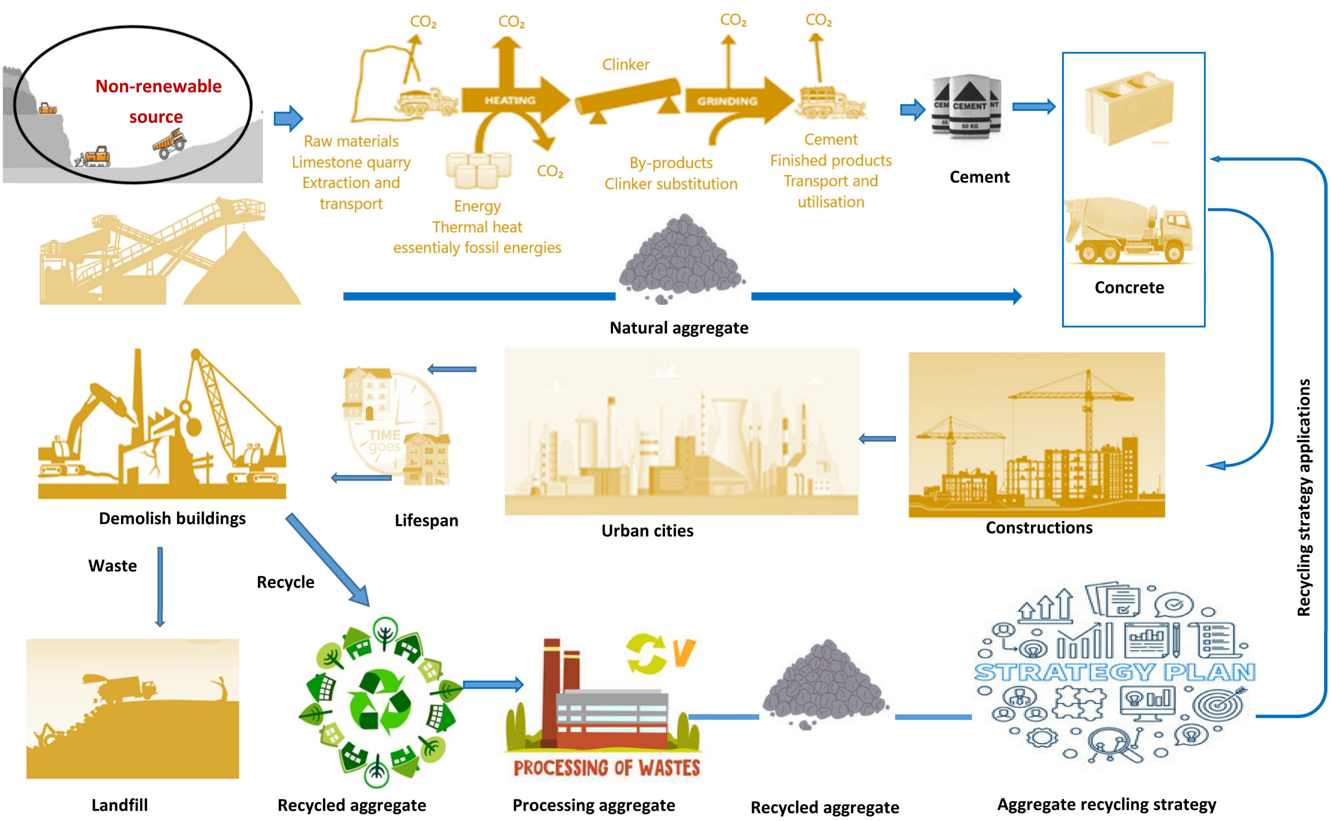


Figure 3. Principles of designing a strategy for RCAs.

2. Vision, Mission and Guiding Principles of Recycled Concrete Aggregate (RCA)

A central component of the solid waste stream is demolition and construction wastes [38,39]. The construction and demolition wastes amount to virtually 25% of total solid wastes globally. According to the U.S. EPA (United States Environmental Protection Agency), the biggest part of construction and demolition materials is concretes that encompass about 70% of demolition and construction materials before recycling. In total, demolition (353.6 million tons) and construction (21.7 million tons) activities account for more than 375 million tons of material [27,40]. About 157.4 million tons of this quantity is generated by road and bridge demolitions. According to the Construction and Demolition Recycling Association, more than 140 million tons of concrete are reclaimed yearly [25,41]. The diversions of construction and demolition wastes in general, and concretes in specific, remain significant areas of interests to policymakers with pressure on landfills continuing to mount. These are also important incentive for the sector.

Eco-friendly concretes can be characterized as those that have RCA in their composition and other alternative elements, which are applied to structural elements [42,43]. The use of natural aggregates, such as sand and gravel, in concretes has become a major global problem, due to the availability of these resources. The substitution of these natural materials in structural concrete by alternatives, such as RCA, is interesting from the environmental perspective and in terms of reducing the demand for natural raw materials. Another point that can be associated is the issue of the disposal of concrete waste, which is taken to landfills, which demand high costs [23,44,45]. The production of RCA is still very little explored on an industrial scale, as there are still gaps related to the standardization of its production process and the need to adapt these industries, such as in acquisition of specific machines for this purpose [46,47]. The potential of production, still little explored, is confirmed in the hesitation of the industries to produce RCAs [27]. There is a tendency in the industries of the construction materials production sector to adapt their industrial plants for the production of RCAs.

The RCAs are obtained after the demolition and crushing process of Portland cement, which create fragments of different characteristics and highly heterogeneous [42]. In the production of nano cement and concrete, from central recycling plants, the level of consistency must be considered up to a certain mixture of materials that have constituents from different sources. The original materials must originate with concrete with specific characteristics, with an adequate quality control of the place of origin of the materials [48].

Concrete is formed of aggregates (fine and coarse), which occupy about 70% of its volume, with the coarse aggregate being responsible for most of this occupied volume. The main function of aggregates in concretes is to fill the cement matrix [21,49–51]. Due to this large consumption, coarse aggregates demand a large amount of material for their production, which in general are linked to natural materials, creating major environmental problems.

Environmental issues related to the extraction of natural raw material for the production of aggregates for the civil construction sector end up arousing interest in the use of RCAs [52]. Obviously, the RCAs have enormous potential for replacing the NCA (natural coarse aggregates), due to the improved cost-benefit ratio and great disposition of the RCA. The main problem with the RCAs is their high variability and the awareness of the contractors as to their advantages. Figure 4 shows some of these concerns.

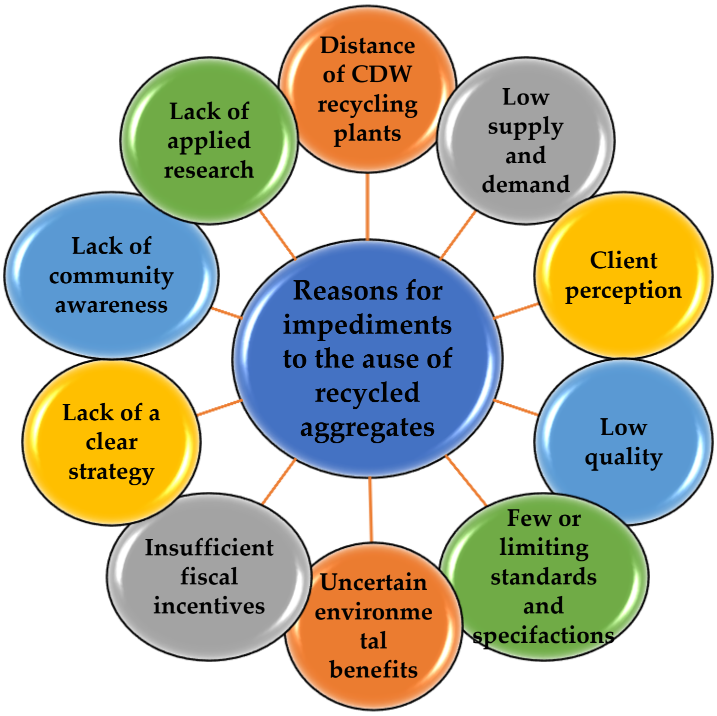


Figure 4. Reasons for impediments to the widespread use of recycled aggregates.

The distance between recycling plants and construction sites is easy to level out. It is possible to erect new buildings immediately on the site of the demolished old ones without additional costs using the simplest crushers and mills.

Low supply and demand is due to the lack of knowledge of this issue on the part of participants in construction. As soon as small and large construction companies start using RCA, supply and demand will begin to develop like an avalanche. The perception of a client will begin to change just as intensively.

Low RCA quality can be greatly improved by careful sorting and crushing. Scientists and practitioners are faced with the challenge of preparing standards and specifications for the use of various types of recycled aggregates.

Confidence has increasingly grown as regards the issue of the environmental benefits of RCA, which is confirmed, among other things, by many papers cited in the current review. With this in mind, it can be assumed that tax breaks will soon be introduced in a number of countries for builders who recycle demolition waste. While there is currently a lack of community awareness, applied research, and a clear development strategy, the current paper and others like it does their part to fill these gaps.

Nano cement and concrete with demolition wastes were estimated to represent almost 50% of material wastes when quantified in terms of weight [20,53,54]. The production of crushed concrete (CCs) is produced through the processing of waste, where the roughest parts are removed and separated, being considered coarse materials. This more crushed part is called fine RCA. The RCAs can also be used as structural grade concrete, as in high-performance structural concrete, depending on strict quality control and a mixing process using silica fumes [42]. A limiting factor for the use of RCAs on a large scale is the related cost in these applications, limiting the environmentally appropriate solutions [23]. As for the technological characteristic of strength to compression, we have that it is reduced by 40% when using RCAs, depending on criteria such as substitution content, humidity, type of RCA, relationship between water and cement and others [55]. One of the characteristics that differentiate natural aggregates in relation to RCAs is their greater water absorption, which alters the workability of concrete. A study has already evaluated that concretes made with dry RCAs, showed a greater slump, in addition to greater density compared to a concrete that uses saturated RCAs [25]. It is known that the existence of lateritic material increases the strength of concretes in relation to the structure's life [41,56–58].

It is known that concrete is one of the most used materials in the world, second only to water [59,60]. The production of concrete consumes a huge amount of natural raw materials, and in countries that have a greater abundance of natural resources, such as Brazil, sand from rivers is used as a natural aggregate, which generates environmental liabilities [61]. In addition to concrete, there is also a huge consumption of mortars and other cementitious materials, in which research has been carried out to apply substitutes to natural materials, such as RCA [62,63]. A problem for many countries is the solid waste generated by the demolition of concrete structures, which has greatly increased in countries that have modernized in recent decades, creating major problems with their disposal, which occurs in general in landfills [64]. The development of research related to the use of RCAs has environmental advantages, and the potential to reduce construction costs, replacing natural aggregates with RCA [65].

Considering that there is a possibility of extracting new aggregates from demolition concrete waste, the production of waste by the construction sector need not necessarily be a problem [42]. Another waste generated during the production of concretes is the sludge generated by the washing process of the transport trucks, which has potential application [66]. Figure 5 depicts the current recycling process of RCAs.

The slurry produced can be sent to a suitable place, after the dehydration and drying process for disposal in landfills, or used to replace NCAs with fine RCAs [20]. The use of blended laterites and RCAs as fine aggregates in concrete can be advantageous in places where the availability of natural aggregates, such as river sand, is readily available.

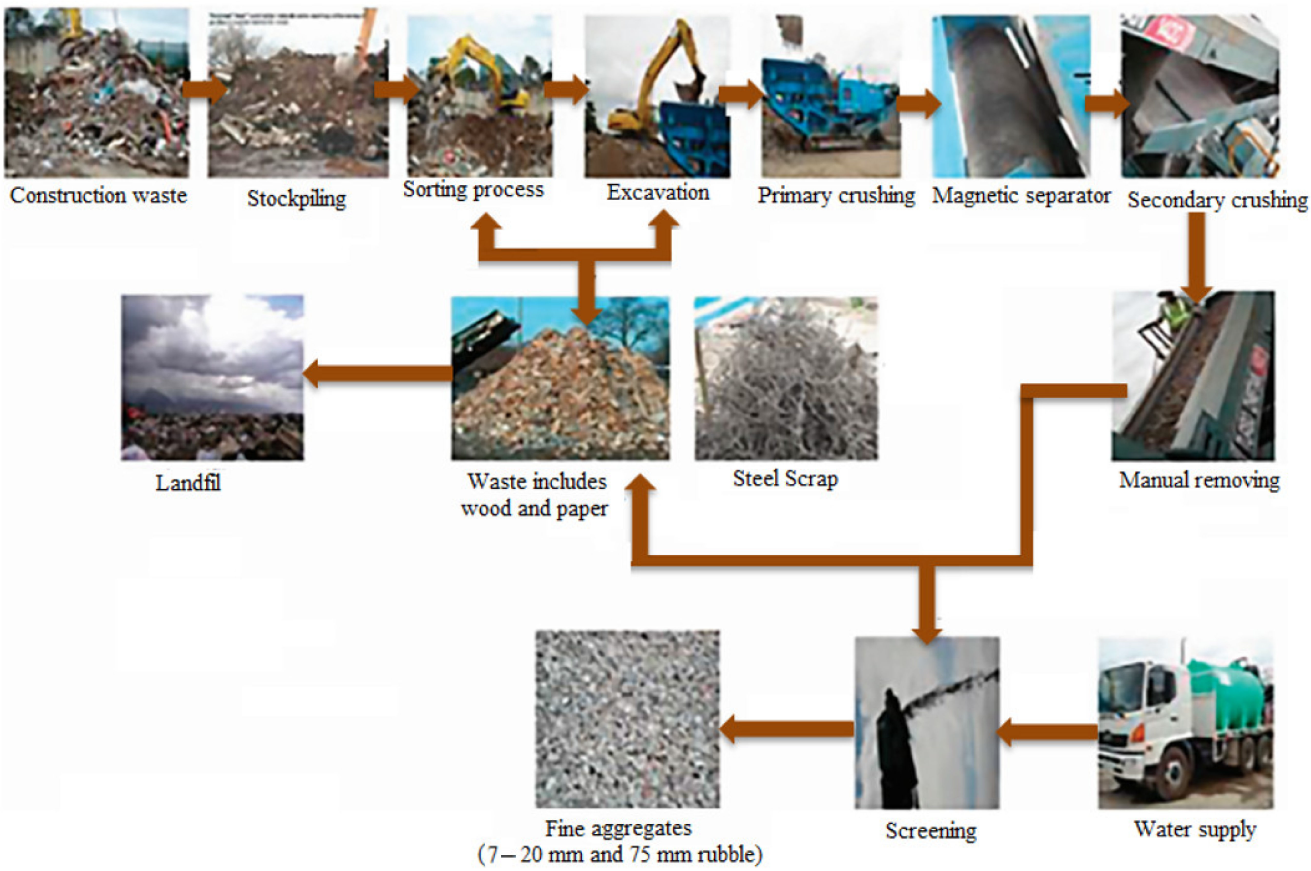


Figure 5. Current recycling process of RCA.

3. Technical and Social Development for RCA

Concretes made with full replacement of the natural aggregate by RCAs can generate concrete of high quality [67]. The use of RCAs in concretes has about 81% of the compressive strength of a concrete produced with natural aggregates. One of the main reasons for the reduction in strength is due to the low density in the transition zones between the paste and the aggregate and other specific properties of the RCA [68]. The use of natural sand has advantages related to the transition area and when replaced by RCAs in up to 20.1% of the reference [69]. One possibility of improving the properties of concrete with RCA is the adoption of extended curing, and adopting pozzolanic materials with the alteration of cement relations. In self-consolidating concretes, which have high strength and performance, the application of RCAs must be used in material selection projects. The dosing process of concrete RCAs can impact their durability and properties in the fresh and hardened states [70]. The restrictions that must be imposed on RCAs is the determination of chemical impurities.

Solid wastes have been unavoidable by-products of industrialized society [71]. An increase in solid waste generation is one economic growth result. The solid wastes were dumped in landfills. The caused air, soil and water contamination from toxic substances like heavy metals, construction chemical, asbestos and polychlorinated bi-phenyls (PCBs) [65]. Strict ecological regulations, the scarcity of landfill areas and industrial growth in developing and developed countries have resulted in the international re-examination of the approaches used to reclaim and use construction and demolition wastes as RCA for infrastructure and construction developments and civil engineering projects. Recycled aggregates generated from construction and development wastes can be used in different civil engineering works depending on their quality. This can help improve the environmental and economic sustainability of various economies [72]. Considerable improvements in recovery rates can be accomplished with the existing technologies in developed countries with further research and development into overcoming market and technical barriers.

Community acceptance is a critical factor that must be taken into consideration to promote sustainability in the construction field. Community concerns about the durability and safety of recycled materials, high costs and negative perceptions are among the prevailing causes affecting the wider social acceptance of sustainable materials [73]. Conducting social awareness programs at all human levels at the local and regional levels will have benefits for accepting sustainable products, especially their long-term environmental benefits to society. The educational programs that have been incorporated and identified are not sufficient; this should be widely marketed in the private sector, in addition to government initiatives. Government initiatives may include offering encouragement and financial incentives to companies and people wanting to adopt sustainable products, this incentive may enhance the social acceptance of sustainable materials [74,75].

4. Economic Development for RCA

Research is currently focusing on assessing the potential for the use of recycled aggregates in concrete, as well as new types of cement and supplementary materials [76,77]. Global society is increasingly concerned with issues related to the disposal of solid waste and the potential for reusing these materials in other segments, fostering the circular economy. In this sense, the application of RCA in traditional concretes fosters the sustainability of the civil construction sector [65]. The use of RCA to the detriment of natural aggregates can be advantageous from the perspective of reducing production costs and high availability. However, a major problem is related to the perception of trust that these materials bring to their users [78]. There is a variety of economic benefits in reclaiming concretes instead of disposing or dumping them in landfills. Few of the advantages of concrete recycling include pollution reduction, saving of transportation and production costs, and conservation of natural resources. In specific, concretes are ideal construction materials for recycling. These benefits include:

- Minimized tip-page and associated freight costs;
- Cheaper concrete sources than newly mined aggregates;
- Landfill space reduction needed for concrete debris;
- Utilizing RCAs as gravels minimizes the gravel mining need;
- High-grade aggregates for road constructions are increasingly available at longer. distances. This increases the costs related to environmental and economic impacts related to the greater haulage distance versus utilizing reclaimed aggregates.

Currently, the booming construction sector in the world is causing increased demolitions of concrete buildings [79]. The demolished are disposed at landfills. The current practices are now leading to large amounts of demolition and construction waste over extensive landfills and are becoming the major sources of land shortages for infrastructure developments [80]. All construction activities require various materials such as wood, mud, clay, glass, stone, brick, steel and concretes. Cement concretes, however, remain the major construction materials utilized in the construction and building sector. The concretes must be such that they can economize and result in proper energy utilizations, safeguard the environment, and conserve resources [81]. The recycled aggregate utilization is especially vital as main parts of concretes are made of aggregates (Figure 6).

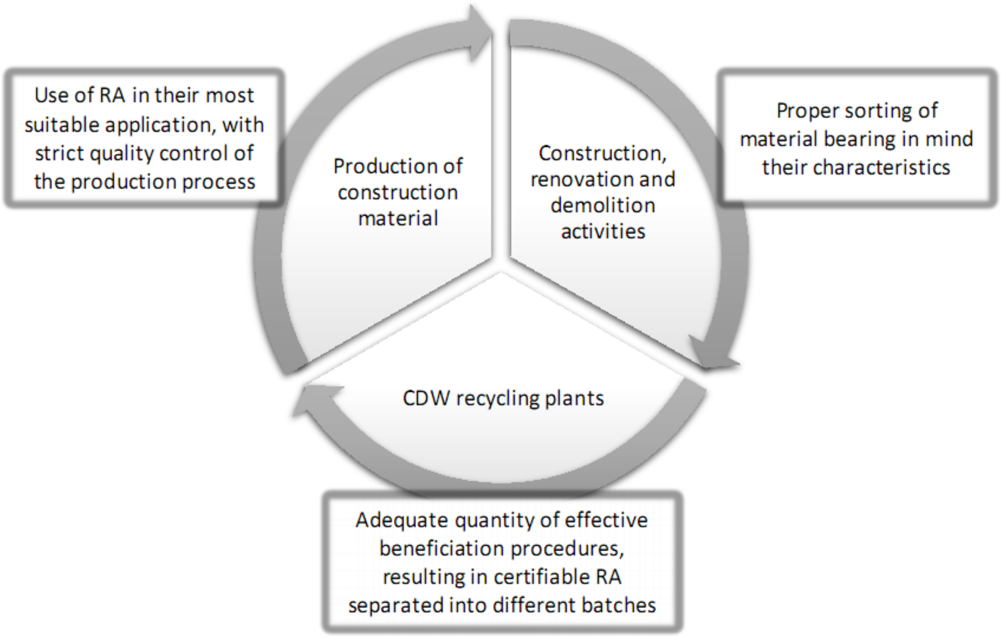


Figure 6. Life-cycle of RCA [82,83]. Reprinted from Ref. [82].

For better economic growth, new constructions are needed. Reclaimed concrete aggregates reduce the need for harvesting, cultivating or mining different materials utilized in building and construction [84]. The reduced production and manufacturing of cements as well has notable economic benefits. Recycled concretes are obtained from processed aggregate debris from demolition wastes, giving the RCA new life in a broad range of applications. Recycled concretes minimize the needs for material mining. Using heavy machines, these resources must be excavated [85]. The process of mining the materials is incredibly expensive and generates many hazardous waste substances. However, utilizing existing reclaimed concrete aggregates largely eliminates the necessity for excavation as a method of obtaining the main materials used in construction. The application of these reclaimed concretes include being broken up into ripraps for standard construction, uses in landscaping and marine structures and secure shorelines. Recycled concrete saves on transporting natural concrete [86]. Most mined concretes have to be transported or shipped to concrete mixing centers for production.

A potential application of concretes with RCAs is in the manufacture of materials with high added value, increasing the environmental and financial benefits [87]. The RCAs have strong potential in the development of a new generation of concretes, and encourage the economic activity of many countries, in addition to the optimization of natural resources [88]. The major challenge in the use and implementation of RCA in new concretes is due to its great variability, coming from different sources. Another aspect is due to the lack of specific regulations on these materials and their application, regarding RCA specifications and their chemical and physical characteristics [89]. Moreover, RCA's negative chemical characteristics can influence the RCA concrete durability and therefore its performance in conditions of service.

5. Economic Development

Properties such as cement content, type of curing, humidity, origin of materials and others, directly influence the final quality of the RCAs. There is still concern about problems more related to physical conditions, such as the size and type of RCA used [90]. The decrease in the RCA concrete performances are associated with the water to cement ratios utilized in mix designs [91]. By contrast with the traditional concretes, those concretes produced with RCA require a greater amount of cement in their mixture and a lower proportion of water, in order to achieve the same mechanical strength to compression.

In traditional concretes with a water/cement ratio of 0.29 the resistance to thawing and freezing was high, while in RCA concretes this strength was inadequate. A possibility to improve this property in RCA concretes is the addition of air in an appropriate way, improving its durability in thawing and freezing [92]. Besides, entrained air application is more successful than reducing the water to cement ratios to enhance RCA concrete resistances to thawing and freezing.

A study has already evaluated that concretes with high levels of cement have high resistance to carbonation [93]. In addition, RCA concrete with high levels of cement tends to achieve greater mechanical strength to compression and traction. On the other hand, RCA concretes in environmental curing present strength problems when compared to NCA lengths, thus concluding that the curing condition has a significant influence on all types of concretes (RCA and NCA) [94–96]. Moreover, the water-cured RCA concrete carbonation depth is virtually double than those of concretes of air-cured RCAs. The reductions in the carbonation depth generated by water-curing could be partly because of greater concrete internal humidity.

The workability assessment of concretes, carried out through the spreading test, depends directly on the free water content in the mixture, thus the humidity of the aggregates has an influence [97]. While the air-dry and saturated surface-dry RCA shows ordinary initial slumps and slump losses, the oven-dry RCAs result in faster slump losses and greater original slumps.

The physical characteristics of the aggregates, such as angularity and texture, directly influence the properties of the concrete in the fresh and hardened state, especially in concretes that use RCA [98]. Also, the concrete finishability and workability can be influenced because of the high RCA absorption. Moreover, the greater RCA pore volumes can influence transportation features (permeability and water absorption), strengths, and the porosities of the concretes.

The replacement of NCA, total or partial, by RCA is affected by the percentages of additions and content. A research project used seven independent variables, and a model was developed that related the quantity and type of aggregate in order to predict the final characteristics of the concrete with substitutions of NCA by RCA from 0 to 100% [98]. In research that evaluated the elastic modulus in concretes, it was found that those using RCA have less modulus and mechanical strengths than concretes using NCA [99]. A higher content of coarse RCA, which leads to an increase in the porosity of concrete, accordingly also increases water absorption (on average by 0.1–0.4%), but reduces the density (2–3%). The article [100] proves that with an increase in the content of crushed recycled aggregates, the resistance to the penetration of chloride ions of concrete decreases, as well as the tensile strength and the compressive strength. In addition, the researchers noted that concrete drying shrinkage decreased with increasing RCA content. Obviously, it is necessary to investigate the quality of recycled concrete to assess its impact on the characteristics of RAC. [101]. Scientists reported that the water absorption of recycled aggregate decreases as the strength of the base concrete increases. This is due to the fact that for concretes with greater strength, a higher cement content is required in principle, and the packing density of the cement composite increases accordingly [102]. Thus, an adjustment to the water content of the mix is necessary for new RCA concretes made from older, harder concretes to obtain the preferred workability. Porous RCAs affect the strength of new concrete. The proportional loss of tensile strength or compressive strength of new concretes due to the use of RCA is more significant when it is obtained from weaker old concretes than from strong old concretes. [103].

There is limited research related to the study of the sources and types of RCA in relation to the properties of concretes [104]. An exception exists in relation to the use of aggregates from the remains of ceramic materials, such as ground ceramic bricks, called “chamotte”, which promote improvement in the mechanical strength to compression, and materials with rough RCA have less strength to compression according to [105]. The use of red ceramic waste in RCAs influences the reduction of the elastic modulus.

Thongkamsuk et al. [106] applied three diverse sizes of aggregate in assessing the RCA size influences on the concrete properties. The greater reductions in the elasticity modulus were derived for the concretes prepared with tinier RCA sizes. On the other hand, they reported that the strengths increase with increases in the optimal RCA sizes. Also, they found that the concrete water absorption reduces with the increases in the maximum RCA sizes [107]. This is because of the comparatively lower contents of weak mortars stuck to large-sized aggregate.

Verian et al. [108] reported results on the effect of RCA on the properties of concrete, and its influence on concrete properties is summarized in Figure 7. Accordingly, multiple studies emerge on the effect of RCA on density, shrinkage, concrete compressive strength, flexural strength, workability, creep and permeability [109]. Moreover, the study showed that the effect of RCA on fracture properties, tensile strength and freezing–thawing resistance are inconclusive [108]. In addition, it is noted that most studies have focused on the mechanical properties of RCA-containing concrete and few have focused on factors known to have a long-term effect, such as freezing–thawing resistance, permeability and creep on concrete containing of RCA.

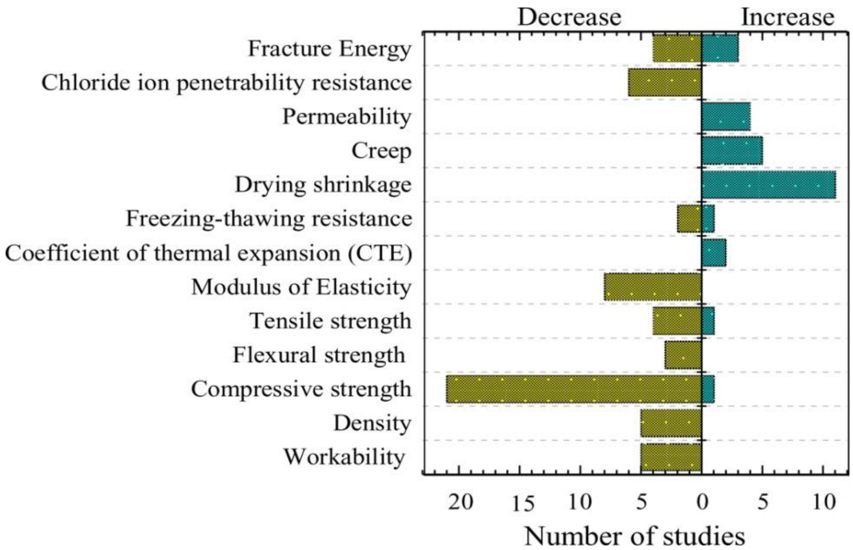


Figure 7. Influence of RCA on concrete properties. Reprinted with permission from ref. [108]. Copyright 2018 Elsevier.

6. Medium-Term Strategy: Maintaining Stability and Sustaining Growth of RCA

Construction projects have proliferated with the modernization and development of societies [32]. The construction tasks are growing in number and at faster rates. The destructions of existing buildings and structures that have attained their service lives also run parallel to activities of construction. It is necessary that the buildings should be destroyed and smashed because of ongoing reconstruction trends and changes in fashion as well as completion of their service lives [56]. The world is looking for healthy buildings to create more space to meet current demands. Construction activities as such are producing waste materials in bulk. These wastes are known as demolition and construction wastes [110]. For the owners, builders, developers and engineers, the disposals of such demolition and construction wastes in a sustainable way is challenging. On the other hand, there are grave shortages of virginally available concretes and aggregates of building of structures while the disposals of construction and demolition wastes are challenge. Reduction of demand in small ways is possible by reusing and reclaiming of demolition and construction wastes produced from construction activities [111]. Therefore, the reclamation of demolished wastes is a sustainable solution for demolition and construction wastes.

Natural resources are scarce [112]. Over time, natural resources will be depleted. Unnecessary waste of natural resources should be regulated and limited to conserve natural resources. Throughout a projects' lifecycle, formulations and implementations of the proper waste management plan can reduce construction and demolition wastes. Most of the construction and demolition wastes can be reclaimed and reused with incorporated resource management schemes and more virgin concrete can be conserved for our future generations [113]. In addition to laws from the concerned regulatory agencies and bodies, recycling success requires promotion by means of information and education.

Strong commitments and investments by private bodies and state agencies are essential to ensure sustainability. Some materials such as glasses and plastics are reused for recycling. Concretes can also be utilized continually in the same manner as long as the specifications are correct [62]. For construction purposes, recycling solid waste products is gradually becoming an important construction and demolition waste management alternative because it overcome the obstacles such as environmental regulations, more restrictive land use and depletion of natural concrete reserves.

The presence of inert material (such as grit from road sweeping, dusts and drain silts) and demolition and construction wastes is important [114]. About 33% of total municipal solid waste is generated from construction and demolition wastes. Recycling of demolition and construction wastes should be focused upon in view of:

- The potentials to save virgin concretes and aggregates such as soils, stones and river sands;
- Their bulks that carried over longer distances for just disposal;
- They are occupying significant space at the sites of landfills;
- Their presence is spoiling the processing of recyclable and bio-degradable wastes.

Demolition and construction wastes have potential applications after grading and processing [115]. Applications of demolition and construction wastes are quite common developed economies. The various state agencies and private bodies responsible for production of waste substances and materials need to separate the produced waste products having potentials for recycling or reuse in future [116]. The engineers in charge should ensure proper treatments of waste products generated from such developments, utilize reclaimed concretes, and choose the materials and types of structures that are appropriate for recycling and reuse [117]. From building and construction, the generation of wastes needs to be reduced. The waste generation should also reduce the hazardous effects from the waste materials generated.

In these processes of demolition and construction wastes' reuse and recycling, the different sub-contractors, agencies and bodies engaged need to collaborate in the steps [118]. The few steps include collections and transportations of wastes, treatments of intermediate wastes that are receiving the wastes, their segregations and further appropriate extensive treatments before putting into the applications [118]. They may establish themselves as compliant contractors or take up important roles. They need to create step-by-step demolition programs and processes. At the beginning of the constructions, different sub-contractors, agencies and bodies need to report anticipated quantities of waste materials by types and treatment plans. There need to be safe treatments of hazardous wastes such as asbestos and effective use of reclaimed aggregate concretes [119]. During construction, the contractors can be requested to submit environmental management program.

To improve the rates of applications of demolished concretes for applications of reclaimed aggregates, all information about construction and demolition wastes by those involved in the process such as contractors and waste treatment firms should be placed in the public domain [120]. This shall help in reducing the quantities of waste materials and promoting reuse or recycling of the construction and demolition wastes. There should also be a demolition plan. While demolishing structures and buildings, demolition plans are needed to embrace systematic approaches to reduce wastes. Demolition plans ensure the best application of construction and demolition wastes. A proposed strategy may be to follow a series of household waste segregations as an initial stage followed by roof finishing, water-proofing materials, exterior and interior finishing materials and electrical and mechanical equipment, then the structures as the last resort [121]. Demolished debris should be temporarily stored in designated areas for the demolition and construction wastes or removed out of the field immediately.

7. Macroeconomic Management of the Utilization of RCA

Current frameworks in material production and recovery, circular economy (EC) and construction and demolition wastes concentrating on reclaiming and reuse indicate steady efforts in fostering a circular economy in the building and construction sector to reduce if not completely do away with the high generation of construction and demolition wastes which raise sustainability issues and threatens the environment [122]. These outlines offer recommendations for future studies and developments into a more successful circular economy in which, rather than linear approaches to disposal, demolition, construction and design of construction and demolition wastes generate huge quantities of construction and demolition wastes [123]. Prolonging the material lifecycle, these frameworks suggest circular approaches or models that allow materials to be remanufactured or reprocessed, thus alleviating the increasing amounts of construction and demolition waste disposed of. A circular economy on processing and material recovery particularly on reclaiming construction and demolition wastes into new building uses is viewed as a viable method to be performed because of the different uses of construction and demolition wastes when remanufactured and reprocessed into new building materials [124]. Construction materials with recycled elements based on the different studies, tests and findings on recycling materials present virtually the same mechanical and physical properties as those of the natural concretes. Quantities of other materials are utilized to compensate for the slight reductions that are negligible compared to sustainability and environmental benefits of recycling construction and demolition wastes in cases in which the mechanical properties are lesser than virgin concretes [125].

When discussed as a whole, the circular economy is broad [126]. This section, therefore, has narrowed concentration to production and material recovery that handles the recycling and reuse of construction and wastes in new building uses. The potential of material recycling and reuse to minimize the ecological impact related to demolition and construction have already gained acknowledgment among policymakers. Despite the market potential and recognition of construction and demolition wastes being restored into new building uses, it is still challenged by obstacles like regulations (12%), logistics (41%), costs (29%) and other factors (6%). Also, there are negative attitudes toward recycled and reused materials perceived by most people as of lower quality but ecologically friendly [127]. If the obstacles to a circular economy cannot be completely removed, then effective foundations for the production and recovery of materials would significantly reduce these obstacles.

Figure 8 illustrates the fundamental processes of how construction and demolition wastes are generated, used and dumped into landfills, or are recycled and reused in broader perspectives [128]. While materials left after demolitions that are not designed for deconstruction are likewise converted into construction and demolition wastes, materials handled by inexperienced labors or excessively ordered materials result in the generation of construction and demolition wastes in building projects. Incineration and disposal in landfills are the normal endpoints of these construction and demolition wastes. The objective of a circular economy is to minimize if not to do away with construction and demolition waste being disposed in landfills and incinerated [129].

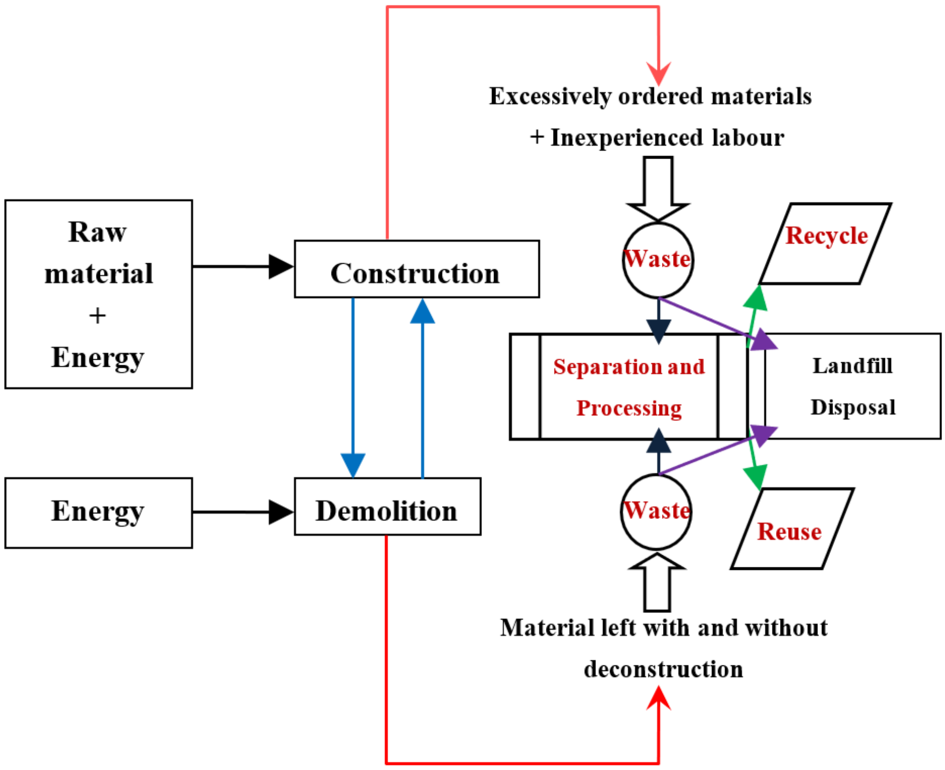


Figure 8. Schematic of demolition and construction materials from start to disposals/end-use [130,131].

The circular economy also concentrates on expanding the quality and scale of reuse and recycling of construction and demolition wastes and their potentials to build new structures.

In the circular economy, effective frameworks need three approaches:

- Narrowing resource loops: application of less material inputs for generation to have fewer outputs of wastes at end of life.
- Slowing loops: this implies the broadening of the application material phase.
- Closing resource loops: this may also be the same as the process of reclaiming the materials.

Closing resource loops is the major approach used for effective frameworks in the recycling and reuse of construction and demolition wastes in production and recovery materials, particularly in the recycling and reuse of materials [130]. In the lifecycle, the recirculation of recovered materials enables their application in new construction uses, avoiding the application of natural concrete aggregates. While recycling needs the breaking down of used materials to generate new items and materials, the practice of utilizing construction materials again is known as material reuse.

8. Restructuring the Public and Private Sectors to the Utilization of RCA

Stakeholders appropriate to RCA utilization including the general public, transportation firms, construction waste disposal organizations, construction firms, local governments, developers, and central government agencies should work together to realize the full potential of RCAs [132]. This work suggests that there should be recommendations to foster recycling of construction and demolition wastes and utilization of RCA, applications and prices of construction and demolition recycled materials such as RCA, RCA promotion, and construction and demolition recycling awareness. Including sector and information technology and finance, environmental protections, transport, municipal administration and landscapes, planning, housing and construction, land resources, development and reform commission, the RCA management of local governments involves various departments of government administration with their respective management responsibilities and privileges [133]. In most cases, the urban administration department, the PRC (People's Republic of China) is the main construction and demolition waste agency. The issues are similar to those at national level at the local government level.

Generally, the stakeholders believe that RCAs are odorless, inert and non-toxic materials. There are minimal complaints about the RCAs [132]. Public safety impacts are not considered and resource and environmental conservation awareness is weak. The government solid waste declarations and building laws, for instance, do not consider RCA at all. There is no provision on construction demolitions. While demolition is overlooked, the management and administration only care about construction [134]. The stakeholders should, therefore, work together realize the applications of RCAs. They should come up with unified calculation standards and RCA production statistical systems. The private and public sector should work together to develop regulations that outline quantitative targets on requirements and standards on RCA pollution control, disposal and recycling and RCA generation that creates hurdles to the real management of RCA. The public and private sectors have to work in ensuring that the mode of RCA generation follows open and planned economy [135]. The RCA administrative department should shoulder law enforcement and supervision activities and bear the qualification approval responsibilities [136]. Cooperation between the public and private sectors integrates enforcement and administration and strengthens the efficiency of macro-management functions that will seriously improve RCA utilization.

Therefore, by implementing comprehensive strategies and practices for managing solid waste from building demolition, the construction sector can gain environmental, economic and social benefits. Accordingly, the importance of waste management and the exploitation of the elements of power, and strengthening them through research, were studied and then highlighted to decision-makers, investors and governments. Table 1 shows the importance of waste management by showing the elements of strength.

Table 1. Elements of waste management for sustainable construction.

Factors of Waste Management for Sustainable Construction	Elements
Environmental aspect	1. Reducing environmental pollution 2. Conservation of water, soil, air and noise 3. Reducing the challenges of global warming 4. Reducing barriers to green development 5. Reducing greenhouse gas emissions 6. Reducing fossil fuel emissions 7. Reducing the depletion of resources and raw materials 8. Reducing the effects of illegal dumping, etc.
Economic aspect	1. Reduce material cost 2. Reducing energy consumption 3. Reducing the number of labor and equipment 4. Saving costs associated with transporting waste 5. Saving costs associated with disposal 6. Reducing valuable land-filled costs of damage waiver 7. Reducing costs of reuse and recycling, etc.
Social aspect	1. Reducing the health and safety impacts of waste in the short and long term p 2. Reducing sorting and disposal effort 3. Strengthening the position of project stakeholders towards CDW (construction and demolition waste) management 4. Persuading public opinion and raising awareness towards CDW management 5. Enhancing the role of incentive to prevent illegal dumping 6. Enhancing the aesthetic effects of recycling stored plants and materials, etc.

The government, design institutes, construction units, and project managers should be involved in generation and utilization of RCA [136]. During the demolition and construction, the project owners are the major players. The project owners are at the center in the source generation stage. While achieving work that adheres to standards and principles, meeting the project owner requirements and completing as many projects in the shortest time possible, the main concerns of design include integrating their ideas into the buildings and structures. The construction departments are interested in how to finish construction with the least cost inputs and resources and at the fastest rates [137]. The government should support more generation and utilization of RCAs. Their obligations, expectations, and responsibilities must be properly coordinated.

9. Social Development of the Utilization of RCA

Increased urbanization rates have resulted in the production and discharge of huge quantities of construction and demolition waste in recent years [138]. It is necessary and beneficial to reuse or recycle construction and demolition wastes from the viewpoints of effective resource utilization and environmental preservation. Currently, recycled concrete aggregates that are generated from construction and demolition wastes are being considered as alternative aggregates for structural concretes [139]. Ecofriendly concretes, reclaimed aggregate concretes generated by partial or complete replacement of virgin aggregates with RCAs in concrete mixes, have drawn a lot of attention in the last 10 years.

Concretes are the most commonly utilized construction materials in the globe due to their cost benefits and favorable material properties [140]. The recent increased rates of urbanization and industrialization have resulted in high international demands for concrete materials. About 20 billion tons of concretes are consumed each year globally.

The growing demand for concrete has raised the utilization of fine and coarse virgin concretes that account for about the total aggregate volumes in concrete mixes. In recent years, the rapid urbanization realized has also led to extensive increases in the demolition rates of old structures, stimulated by the restricted availabilities of new construction sites [141]. In turn, this has resulted in the production and discharge of huge quantities of demolition and construction wastes. In most countries, these wastes account for a large part of solid wastes. These wastes are also ineffectively and usually disposed of in landfill at substantial costs, leading to in the landfill space depletion. Over the last 20 years, recycled concrete aggregates that are got from demolition and construction wastes have been viewed as alternative to virgin concretes in structural concretes to minimize the environmental impacts of construction and demolition wastes and converse natural aggregate resources [142]. Currently, it is appreciated that the applications of RCAs for generations of RAC is a promising and highly attractive technology for reducing the ecological impacts of the construction sector and conserving natural resources.

Environmental protection is one of the main problems of our present society [143]. In this respect, some of the notable components are consumption of waste materials and reductions of the consumptions of natural raw materials and energy. Increasing demands for housing and rapid infrastructural developments such as airports and highways has resulted in scarcity and increase in costs of construction materials. Most construction and demolition wastes are disposed of and dumped in landfills. In urban areas, disposing and dumping construction and demolition wastes on landfill is causing shortages of dumping places [144]. At various construction sites, huge amounts of demolished concretes are available. Many old bridges, concrete pavements, old buildings and other structures have exceeded their use limit and age because of structural deterioration beyond repair and should be demolished. Even adequate to use structures are demolished because in the present scenario they are not serving needs. The structures are changed into debris originating from natural disasters such as floods, cyclone, and earthquakes. To save energy, the environment and costs, it is therefore appropriate to begin reclaiming and re-using demolition concrete wastes [145]. In building and construction, the applications of reclaimed aggregates from demolition and construction waste is showing prospective applications. Figure 9 presents the recycling of gypsum plasterboard [115].

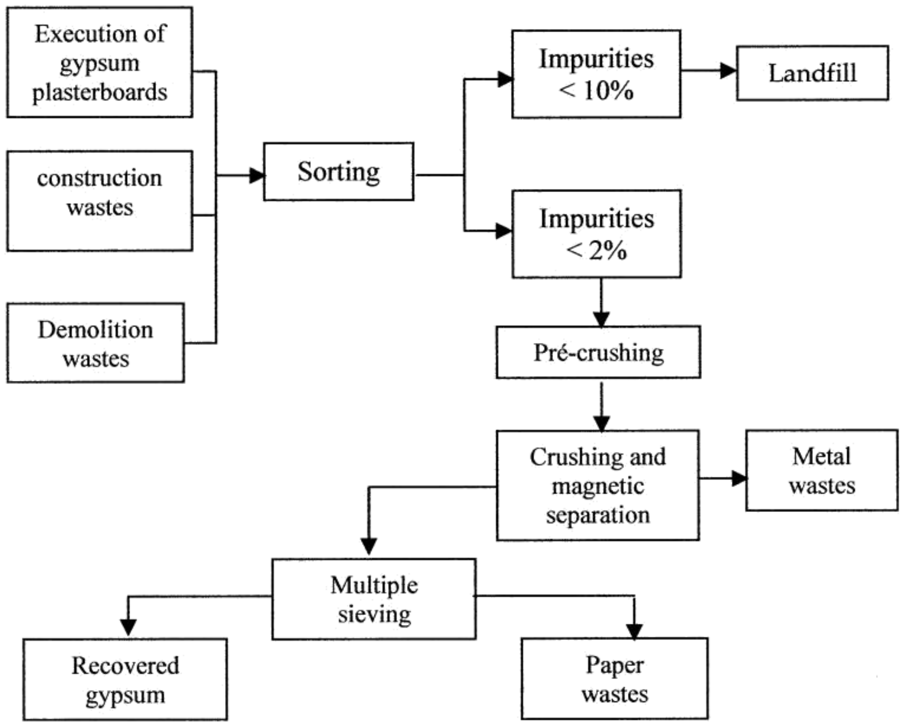


Figure 9. Recycling of gypsum plasterboard [115,146].

10. Economic Development of the Utilization of RCA

In this research, the economic analyses are conducted by means of whole industrial chain comparative analyses and empirical analyses [147]. From the entire generation process of construction and demolition waste recycling, the cost components of production, sorting, removal, transportation, digestion and beneficial application of RCA are analyzed [148]. Comparative analyses and cost calculations are carried out by standardized data processing means sampled from individual cases of construction and demolition landfills, fixed crushing construction and demolition waste recycling, and mobile crushing construction and demolition waste recycling [98]. Prices of common construction material products and recycling products and costs of various construction and demolition waste recycling technologies are analyzed and compared.

The analyses indicate that technologies of construction waste recycling generate marginal economic gains. It is very hard for all types of recycling facility to be financially feasible without proper subsidizing instruments and policies [42]. Fixed treatment technology products have better marketing advantages than mobile treatment technologies that are restricted by process equipment despite their higher investment costs. In the research, the funding cost of various types of facility has not been considered. All the investments made by the enterprise are considered fully with their capitals [100]. The economic benefits of both mobile and fixed technologies are anticipated to be lower if such financing costs are taken into consideration. That is one of the hurdles to market construction waste recycling technology applications.

There are no stable sources of material for construction waste recycling firms because of the absence of measures for transportation and mandatory dumping of construction wastes according to the study, leading to the absence of revenue stability for factories involved in production and also having certain effects on market sustainability, for instance, fixed construction waste recycling [101]. In the market, the sales price is not a hindrance affecting market applications of RCA since there are scenarios in which their costs are lesser than products of common construction materials. This is more a market acceptance factor of recycled concrete aggregates. In the sector, the absence of accreditation identification systems and uniform quality certification and their narrow applications cause some marketing problems.

In this stage of quantitative research, the main methods used for the collection and analysis of data from countries located in Southeast Asia will be shown, through an experimental method. The composition with RCA and fly ash will be compared with conventional concrete, composed of cement and natural aggregates (sand) in relation to air quality and emission of atmospheric pollutants (SO_2, NOx, and volatile organic compounds). This research will also be directed at reviewing the best control strategies related to the optimization of the manufacture of RCA and fly ash, aiming to minimize the costs and environmental impacts.

According to the American Concrete Institute (ACI), mixtures were made for two types of unconventional concrete, the first using reclaimed concrete aggregates and the second fly ash, for later evaluation of technological parameters. The dosage of the components was carried out according to data in the literature, and the molding took place in specimens of 3 × 6 inches, which were cured at natural temperature for one week and one month. The specimens were dosed for a mechanical strength to compression of 17 MPa. In each analysis, five specimens were made, making it possible to determine the average value. Of these samples, two were for one-week cure tests, two for one-month cure and the rest for additional tests. In addition to the different mixtures with admixtures, a reference was considered (without any additions). For both fine and rough concretes, moisture contents, sieve analyses, and unit weight measurements were completed before mixing, as indicated in Table 2. The water contents in the fine concretes was higher than the water contents in the coarse concretes. For both coarse and fine concretes, the unit weight was ranging between 105 lb/ft^3 and 95 lb/ft^3.

Table 2. Aggregates characteristics.

Materials	Moisture Content (%)	Unit Weight (ln/ft^3)	Fitness Moduli
RCAs	4.00	95.00	5.32
Fine aggregates	5.81	95.10	3.01
Normal aggregates	0.02	100.02	5.13

The specimens of 3 × 6 inches were made using a plastic mold, meeting the requirements of the standard ASTM C470/C470M. According to ASTM, all specimens were made for the respective tests in a controlled environment. Slump tests according to ASTM C143, and air content according to ASTM C231 were carried out. The X-ray diffraction (XRD) blends had a good slump, ranging from 76.20 to 101.60 mm requirements. The air content varied from 1.80 to 2.00%. The used water/cement ratio of concrete was 0.750 for alternative types of concrete.

In the analyses, equipment within appropriate ASTM standards were used. In the case of the air content test, a 2786 C measurement was used. For the evaluations in the hardened state, all curing periods again followed the recommendations for technical standards. Table 3 lists the tests performed on cement composites. Figure 1 schematically shows the mixing, shaping, curing and testing of concrete.

Table 3. Tests carried out on cement composites as per the ASTM standards.

Materials	Test Method	Descriptions
Unit Weights	ASTM C138	Determined by density
Slumps	ASTM C143	Determined by workability
Air contents	ASTM C231	Determined by freshly mixed concrete air content by pressure methods
Compressive strength	ASTM C39	Determined by a press

The dosage of the materials in terms of mass allowed the determination of the proportions, aiming at a mechanical strength compression of 17 MPa. Various proportions of RCA were used and the final dosage of the mixtures is shown in Table 4. The mixtures had an increased water–cement ratio (0.75). It was used 100, 75, 50 and 30% recycled aggregates. The reference mixture also was included in the experimental program.

Table 4. Mix design.

Materials	% Replacements of Fly Ash			
	1st Trial (30%)	2nd Trial (50%)	3rd Trial (75%)	4th Trial (100%)
RCA (Ibs)	5427.00	904.00	1446.00	1717.00
Fine aggregate (Ibs)	1578.00	1578.00	1578.00	1578.00
Normal aggregate (Ibs)	1231.00	877.00	351.00	0
Cement (Ibs)	433.00	433.00	433.00	433.00
Water/cement ratio	0.750	0.750	0.750	0.750

In the civil construction sector a constant concern is the costs related to the materials used, which also calls for care with sustainability [42]. An alternative to traditional materials, in order to reduce building costs, is the application of the concepts of circular economy, which assist in the introduction of solid waste in the concrete production process, for example. Studies dedicated to understanding the price dynamics of fine and coarse aggregates are important to determining the final cost of concretes [149]. One of the main elements that changed the cost of concrete, according to Table 5, was the use of RCA and fly ash, in addition to the cement itself [150]. At its cheapest, about 12 cubic yard of reclaimed concrete aggregated can be bought at $13. The prices differ regularly. It is important to note that RCA can be obtained without any training in several countries, where its reuse is encouraged by local governments. For this research the RCA was obtained for free by grinding manually. Sand and crushed stone is purchased at a price of $16–19 per ton [151]. The cost of the mixing water was about $9 per 1000 gallons. In addition, there are many other important aspects when analyzing costs, such as labor costs, shipping costs, and taxes [42]. The cost of these additional costs varies greatly from region to region. Therefore, the cost analysis for this study focused on the cost of materials.

A cost comparison was undertaken for the replacement of recycled aggregate in amounts (100%, 30% and 50%) in a fly ash cement composite when compared to conventional concrete [152]. Although the strength was 50 psi less than the target strength of 2500.00 psi compared to conventional concrete, fly ash concrete with 30.00% fly ash was 15.20% cheaper. Concrete with 50% fly ash can save 26.5%. However, the strength was a minimum of 2500 psi. Despite the lack of noticeable savings (5.6%), the use of RCA can replace virgin concrete up to 100% [3]. However, when purchased free, RCAs minimized costs by 19% compared to conventional concrete. In addition, if we also take into account the income for the disposal of construction waste, then the costs for the manufacture of cement composites are reduced even more.

Table 5. Cost comparisons of conventional concrete and RAC per $/yd^3.

Material	Regular Concrete			100% Recycled Aggregates	
	Unit Cost ($/lb)	Quantity (Ibs/yd^3)	Total Cost ($/yd^3)	Quantity (Ibs/yd^3)	Total Cost ($/yd^3)
Recycled aggregates	0.0066	-	-	1755.76	11.59
Fine aggregates	0.0090	1583.24	13.46	1583.24	13.46
Coarse aggregates	0.0098	1755.76	16.68	0	
Cement	0.1380	433.33	56.33	433.33	56.33
Water	0.0010	237.67	0.24	237.67	0.24
Total cost	-	-	86.47	-	81.62

The need for an ABC (activity-based costing) strategy for applications makes the creation of RCA manufacturing plants worthwhile. In the study [33], a method was presented to determine the current volatility in RMC factories, as shown by plant revolutions and people. The researchers noted that fluctuations in demand resulted in about 3% of all plant closures. In addition, it also provides facts about the overall RMC manufacturing sector and the current cost structure revolving around the RMC industries. Given the capital intensity of the industry, the paper [38] noted that the raw concrete used accounts for up to forty-five percent of the sector's annual revenues. A study of the labor component of the industry showed that payments and wages to subcontractors accounted for 5.10% in subcontracting payments and 11.30% in wages. While depreciation was 4.20%, internal and external, transportation costs accounted for only 15.0% of the sector's total revenues. It is also argued that operating and utility costs, including natural gas, electricity, diesel and water in companies, as a whole, account for the rest of the balance sheet. There are models that managed the main political interventions associated with the recycling process, construction and demolition solid waste management and help the demand for recycled products. Another point is the research related to the viability of the recycling processes of the waste produced and their respective costs, since in general the costs of RCA are higher in relation to NCA. However, this research was restricted to the most important features of the RCA, not addressing in-depth cost issues. Table 6 analyzes the building wastes.

Table 6. The amount of building wastes generated during the construction stage.

Material	**Waste Quantity (kg/m^2)**			
	Monteiro et al. [153]	**Bohne et al. [154]**	**Tozzi [155]**	**Mariano [156]**
Ceramics	-	-	17.65	2.55
Concrete	87	19.11	3.0	9.08
EPS (expanded polystyrene)	-	0.21	-	-
Fiber cement	-	0	-	0.63
Glass	-	0.12	-	-
Gypsum	-	1.38	-	-
Hazardous	-	0.07	-	-
Metals	-	-	0.48	-
Mortar	189.0	-	18.33	2.93
Others	-	6.19	-	1.94
Paper	21	0.46	0.58	0.16
Plastic	-	-	2.43	0.04
Wood	3.0	2.75	0.87	16.82
Total	34.15	300.0	30.77	42.89

11. Implementation, Monitoring and Evaluation of the Utilization of RCA

Development of crack in RAC columns is similar to that of concrete column made from virgin concrete [157]. However, some studies reviewed by Xiao et al. [135] reveal that RAC columns developed cracks quite early and in an abrupt manner compared to natural concrete columns. Zhou et al. [158] found that an increase in the content of RCA reduced the bearing capacity of columns made from recycled concrete. The study, however, concluded that the change in bearing capacity as the amounts of RCA changed was not significant. The study found that the failure mechanism of columns made from RCA was similar to that of natural concrete under big eccentric compression. However, there was more deformation in RAC columns compared to natural concrete columns. Kliszczewicz and Ajdukiewicz [123] found that columns made from recycled aggregate and those made from virgin aggregate had similar bearing ability. However, the study showed that RAC columns underwent more deformation when compared with natural concrete columns [108,159]. The study concluded that the capacity of concrete to bear loads may be neglected when using RCA in construction. Figure 10 shows the research methodology of sustainable utilization of RCA.

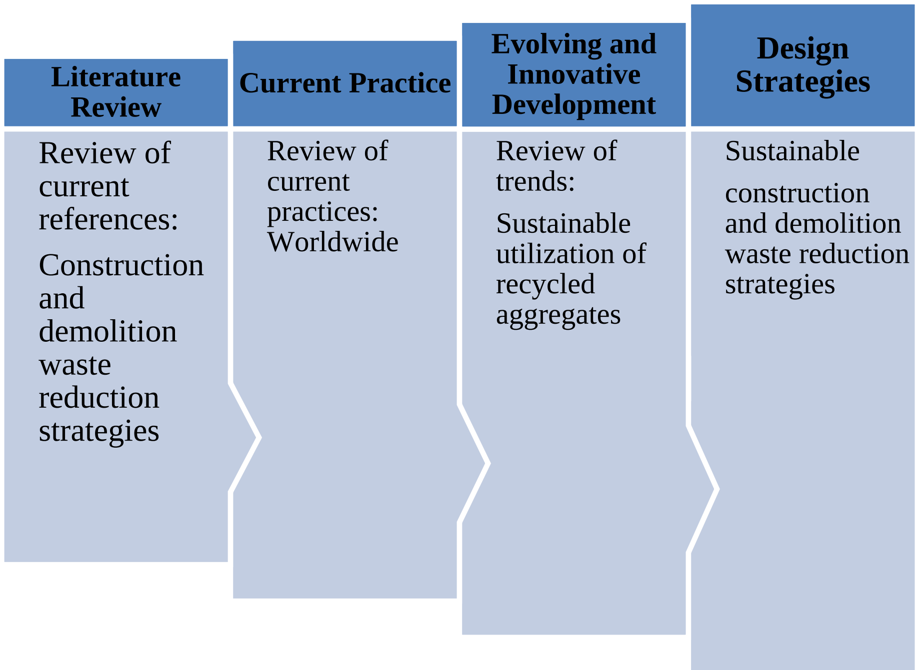


Figure 10. Research methodology of sustainable utilization of RCA.

12. Conclusions

A review of the status and future prospects of a design strategy for recycled aggregate concrete has identified the following elements:

- Currently, the use of RCA is hampered by a number of disadvantages, which include the distance between processing plants and construction sites, low supply and demand, poor RCA quality, lack of standards and specifications, etc. While there is currently a lack of community awareness, applied research and a clear development strategy, this document and others like it do their part to fill these gaps.
- Concretes made with full replacement of the natural aggregate by RCAs can generate concrete of high quality. One possibility of improving the properties of concrete with RCA is the adoption of extended curing and adopting pozzolanic materials with the alteration of cement relations.
- A potential application of concretes with RCAs is in the manufacture of materials with high benefit, increasing the environmental and financial benefits. The RCAs have great potential in the development of a new generation of concretes, and encourage the economic activity of many countries, in addition to the optimization of natural resources.
- Economic benefits include minimized freight costs; cheaper concrete sources than newly mined aggregates; landfill space reduction needed for concrete debris; utilizing RCAs minimizes the gravel mining need etc.
- A proposed strategy may be to follow a series of demolition waste segregation, such as roof finishing, waterproof materials, exterior and interior finishing materials etc.
- Closing resource loops is the major approach used for effective frameworks in the recycling and reuse of construction and demolition wastes in production and recovery materials, particularly in the recycling and reuse of materials. In the lifecycle, the recirculation of recovered materials enables their application in new construction uses, avoiding the application of natural concrete aggregates.
- Government, design institutes, construction units, and project managers should be involved in the generation and utilization of RCA. During the demolition and con-

struction, the project owners are the major players. Their obligations, expectations, and responsibilities must be properly coordinated.

- Over the last 20 years, recycled concrete aggregates that are obtained from demolition and construction waste have been viewed as alternatives to virgin concretes in structural concretes to minimize the environmental impacts of construction and demolition waste and conserve natural aggregate resources. Currently, it is appreciated that the applications of RCAs for the generation of RAC is a promising and highly attractive technology for reducing the ecological impact of the construction sector and conserving the natural resources.
- In the market, the sales price is not a hindrance affecting market applications of RCA since there are scenarios in which their costs are lesser than products of common construction materials. It is more a factor of market acceptance of recycled concrete aggregates. In the sector, the absence of accreditation identification systems and uniform quality certification and their narrow applications cause some marketing problems.
- With proper preparation of the RCA, the concretes with standard physical and mechanical properties and performance characteristics can be obtained.

Author Contributions: N.M., R.F. and M.A.; Data curation, M.A., A.M.Z., S.K., R.F., N.V. and M.K.; Formal analysis, I.C., M.A. and T.O.; Funding acquisition, M.A., R.F., N.V. and M.K.; Investigation, N.M., I.C., M.A. and M.K.; Methodology, N.M., M.A. and A.M.Z.; Project administration, M.A., R.F., N.V. and M.K.; Resources, M.A., M.K., I.C., R.F., N.V. and N.M.; Software, S.K. and R.F.; Supervision, N.M. and R.F.; Validation, M.A., N.V. and T.O.; Visualization, N.M. and R.F.; Writing—original draft, M.A., A.M.Z., S.K., R.F., N.V., A.A. and M.K. All authors have read and agreed to the published version of the manuscript.

Funding: The research was funded by the Ministry of Science and Higher Education of the Russian Federation as the grant Self-Healing Construction Materials (contract No. 075-15-2021-590 dated 04.06.2021).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data sharing not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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