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Adopting Recycled Aggregates as Sustainable Construction Materials: A review of the Scientific Literature

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Abstract

Adopting a holistic three-step literature review workflow, a total of *1,639* journal articles were used in this study as the literature sample related to recycled aggregate (RA). This study summarized the existing research topics focusing on RA, gaps of current research, suggestions for promoting RA usage, and research directions for future work. A research framework was also proposed linking the existing research themes into trends in RA research. This review

work serves as a foundation work to bridge the gap between scientific research and industry practice, as well as to guide the directions in RA-related academic work using an interdisciplinary approach.

Keywords: Circular economy; recycled aggregate; construction waste; sustainable concrete; literature review

1. Introduction

Over the last decade the concept and development model of Circular Economy has been gaining a growing attention [1]. It aims to provide an alternative to the traditional and dominant model [2] featured at consuming resources and then disposing it. Circular Economy emerges through three main actions, namely reduction, reuse, and recycle [3]. According to Ghisellini et al. [1], waste management, as a recovery of resources and environmental impact prevention, has become an important sub-sector of Circular Economy. Around 30% to 40% of the urban solid wastes come from construction and demolition (C&D) activities [4].The overwhelming amount of C&D wastes generated in the forms of concrete, bricks, and tiles are causing pressures on the limited urban landfill space [5]. On the other hand, limited natural resources, such as virgin aggregates, call for the utilization of recycled alternatives to meet the construction industry needs [6].

The increasing needs for sustainability in the construction industry and the movement of Circular Economy is driving the research of recycling and reusing waste streams, such as recycled aggregates (RAs) obtained by crushing C&D wastes. RA was identified [7] as one of the main research topics in the domain of C&D waste management. It is a typical product after the initial treatment of C&D wastes (e.g., old concrete). So far, limited research has been performed to provide a holistic overview of the RA-related scholarly work. However, a review of RA-based research is important for multiple stakeholders including engineers, policy makers, and academics based on the facts that: (1) it is a concrete example of waste management strategy in the micro level of Circular Economy as proposed by Ghisellini et al. [1]; (2) it is the main form that C&D wastes are processed for reuse to reduce the demands on natural resources and to release the landfill pressure; and (3) the utilization of RAs in the construction sector has multiple effects to the cleaner production in terms of social, economic, technical, and environmental aspects. The technical and environmental effects of adopting RAs have been widely studied according to existing literature, such as how the cement composite products' quality would be affected by reusing RAs [8], and the carbon emissions of adopting RAs [9]. The cost factors (e.g., labor and equipment inputs) of adopting RAs have also been considered in reusing RAs as the alternative approach to consuming natural aggregates [10]. The social aspect in the cleaner production includes education and training aiming to produce sustainable outcomes, to raise public awareness, and to change the public attitudes as indicated by Kjaerheim [11]. Social aspects involved in adopting RAs include the public awareness, governmental policies, social value and cultural acceptance towards using RAs [12, 13].

Adopting a holistic literature review approach by incorporating text-mining method in the RA literature sample followed by an in-depth discussion, this study aims to provide answers to the following research questions: (1) what are the mainstream research topics or themes in the RA domain? (2) what are the current research gaps and challenges of adopting RAs for a cleaner production? (3) what recommendations could be made to promote the usage of RAs in the construction industry? and (4) what could be the promising research directions for future scholarly work?

Existing review-based studies [14, 15] have targeted on the applications of RA in concrete production, especially the investigation of properties of recycled aggregate concrete (RAC) containing RAs. Some of the existing review-based studies [16-18] have been focusing on RAs using C&D wastes, such as old concrete. Silva et al. [19] provided the review of the fresh-state performance of RAC; Guo et al. [20] targeted on the durability issue of RAC; Tam et al. [21]

extended the scope of RA into the general applications in concrete. Based on these prior studies, researchers believe that some further work could be performed. For example, a more comprehensive review for RAs in terms of its sources and applications could be provided. It is worth noting that the source of RAs may not be limited to C&D wastes, but may also include other industrial waste streams, for instance, agricultural and aquaculture by-products [22], urban or industrial wastes such as oyster shell [23], bottom ash [24], and rubber [25]. Furthermore, the application of RAs may not be limited to concrete mix design and production [26], but can also include other uses such as pavement base [27], roadway construction [6], and other cement composites [28].

Besides the need for the review of RA in a wider scope in terms of its sources and applications during the life cycle process, the text-mining-based scientometric approach could also be adopted in assisting the literature review of RA-related studies. As stated by Song et al. [29] and Hosseini et al. [30], several existing review-based studies were prone to subjectivity, either due to limited literature sample or because of researchers' pre-selection of journal sources in a given research domain. To address this issue of subjectivity or biasness in literature search, more recent review-based studies [31, 32] introduced the scientometric analysis approach by incorporating the text-mining method in analyzing the contents within a larger sample of literature. By adopting the scientometric analysis, articles and keywords that are influential in the given research domain could be summarized in a quantitative way. Aiming to address the research gaps in RAs in terms of its scope and review method, this study aims to achieve these following objectives: (1) establishing a comprehensive literature sample covering a wider scope of RA-related studies; (2) identifying the mainstream keywords and influential articles that are active in RA research; (3) adopting a further in-depth discussion for linking the existing research themes in RA to future research directions; and (4) providing suggestions for enhancing the RA usage. The novelty of this study lies in that: (1) it provides a more comprehensive coverage of RA-related research topics from a potentially larger literature sample; and (2) it moves forward from several existing studies applying scientometric review [29, 33] by utilizing the text-mining outputs for further in-depth discussion, which would then initiate a research framework guiding future scholarly work in RA-related studies as well as propose recommendations for promoting RA usage in the construction sector.

The following sections of this study are structured as: Section 2 describes the review methodology consisting of three steps; Section 3 presents the results of the scientometric analysis conducted to the literature sample of RA; Section 4 extends the scientometric review from the prior section into a further in-depth discussion; Section 5 concludes this review-based study.

2. Methodology

This study was based on a three-step workflow to evaluate the research outputs in RAs. Fig.1 describes the review steps adapted from Xu et al. [31], consisting of bibliometric search of literature using *Scopus* as the database, scientometric analysis adopting *VOSViewer* as the text-mining tool [34], and the follow-up qualitative discussion. The scientometric review approach, as described by Hosseini et al. [30] and Song et al. [29], could address the biasedness or subjectivity problems in previor studies in the construction sector (e.g., Tang et al. [35]). However, some existing scientometric analysis-based review (e.g., Zhao et al. [36]) are also limited to the self-explanatory discussions such as who are the most produtive sholars in the research domain. Aiming to address both limitations in these two literature review approaches, this study provides a more comprehensive approach as shown in Fig.1 by combining the text-mining method and the in-depth discussion.

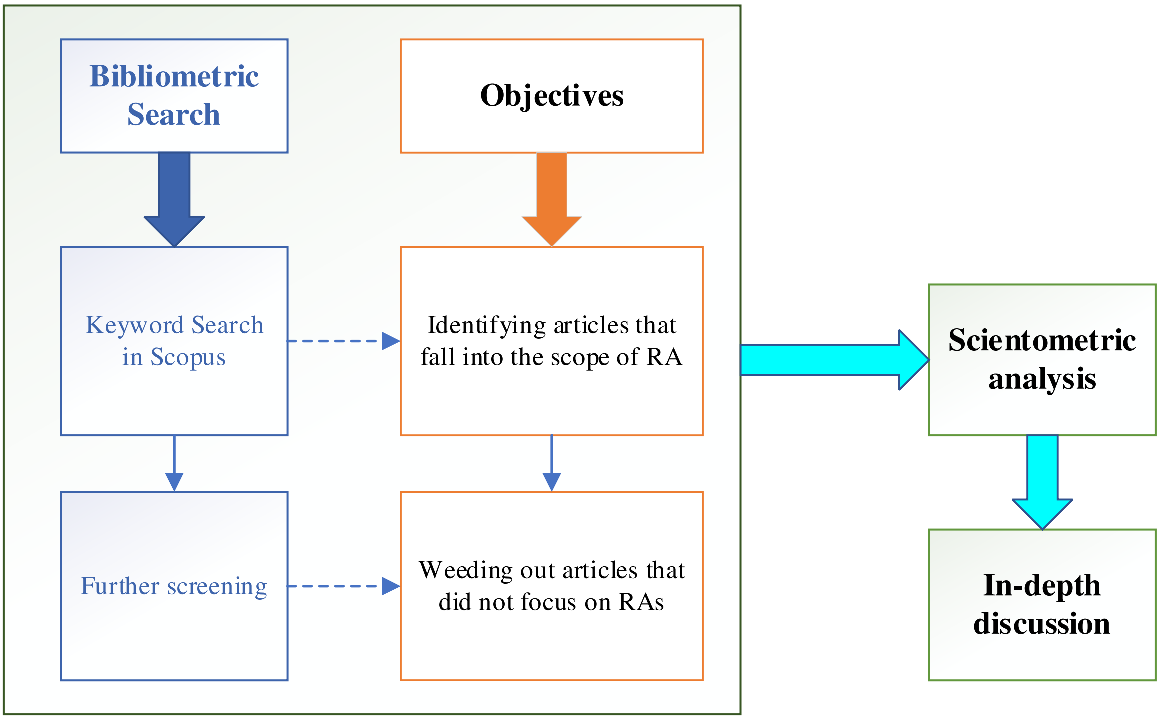

Fig.1. Description of three-step literature review of RA-related studies

2.1.Bibliometric search

The bibliometric search of RA-related research was conducted in *Scopus*, which was defined by Aghaei Chadegani et al. [37] with a wider coverage of articles and more recent publications compared to *Web of Science*. The keyword input and filtering of publications in *Scopus* is shown below:

TITLE-ABS-KEY (*"recycled aggregate"* OR *"recycled aggregates"*) AND (LIMIT-TO (DOCTYPE , *"ar"*) OR LIMIT-TO (DOCTYPE , *"re"*)) AND (LIMIT-TO (LANGUAGE , *"English"*)) AND (LIMIT-TO (SRCTYPE , *"j"*))

Only journal articles including review papers published in English were recruited for literature review in this study. As seen in Fig.1, extra sub-steps (i.e., further screening) were performed to screen out initially selected articles that did not target on RA research. These articles, which barely mention RA in their texts but not really focus on RA-based research, would be removed from the initially identified literature sample. During the further screening process, all the eight researchers in this study reviewed the title, abstract, and keywords of the initial literature sample. Discussions were held among researchers to agree on the decision of removing each of these articles.

2.2.Scientometric analysis

Based on the literature sample finalized from the prior step, all the articles were uploaded to *VOSViewer* for scientometric analysis. *VOSViewer* was described by van Eck and Waltman [38] as a tool that provided a distance-based visualizations of bibliometric networks, especially for visualizing larger networks with text-mining functions. Some existing studies in other research domains adopting *VOSViewer* can also be found, such as Song et al. [29] in project management, and Xu et al.[31] in cement composites reinforced by graphene oxide. Similar to the study of Jin et al. [7], *VOSViewer* was utilized in this study to: (1) load the RA-based literature sample from *Scopus*; (2) compute, and evaluate the influence of mainstream documents and RA-related research keywords; (3) summarize the main existing research keywords in this domain.

2.3.Qualitative discussion

Following the scientometric review, a further in-depth qualitative discussion was conducted to address the three main research questions related to: (1) the mainstream research topics or themes within RA; (2) the limitations of existing research; (3) suggestions for promoting RA usage in the construction sector; and (4) recommendations for future research in RA. The discussion also aimed to propose a research framework that could link existing research topics into future directions in RA-related scholarly work.

3. Results of scientometric analysis

The keyword inputs in *Scopus* initially generated a total of *1,652* journal articles published between 1984 and 2018. These journal articles were initially screened by the research team of this study to remove those which did not focus on RAs. Excluding those not targeting on RA research, the remaining *1,639* articles were agreed by the research team as the finalized sample for further literature review.

3.1.Articles influential in recycled aggregates

The total *1,639* articles selected for literature review are ranked according to the total citation . Table 1 provides the ranking of most influential articles evaluated by the total citation.

Table 1. Most influential articles measured by Total Citations in the RA domain

Reference	**Article Title**	**Total Citation**
Etxeberria et al. [39]	Influence of amount of recycled coarse aggregates and production process on properties of recycled aggregate concrete	490
Xiao et al. [40]	Mechanical properties of recycled aggregate concrete under uniaxial loading	360
Evangelista and de Brito [41]	Mechanical behaviour of concrete made with fine recycled concrete aggregates	339
Sagoe-Crentsil et al. [42]	Performance of concrete made with commercially produced coarse recycled concrete aggregate	328
Poon et al. [43]	Effect of microstructure of ITZ on compressive strength of concrete prepared with recycled aggregates	326
Katz [44]	Properties of concrete made with recycled aggregate from partially hydrated old concrete	314
Poon et al. [45]	Influence of moisture states of natural and recycled aggregates on the slump and compressive strength of concrete	299
de Juan and Gutiérrez [46]	Study on the influence of attached mortar content on the properties of recycled concrete aggregate	297
Tam et al. [47]	Microstructural analysis of recycled aggregate concrete produced from two-stage mixing approach	295
Ajdukiewicz and Kliszczewicz [48]	Influence of recycled aggregates on mechanical properties of HS/HPC	285

Table 1 provides ten top ranked articles in terms of total citation. It could be inferred these articles in Table 1 tended to unanimously focus on mechanical properties of cement composites adopting RAs. Nevertheless, it can be found that some more recent studies have extended the mechanical properties to durability of RAC [49-51] as well as computing and modeling methods [52, 53]. More studies [54-56] applying data science methods (e.g., data mining in sustainable concrete) can be found in recent years. Researchers have also started reviewing literature of how RA affect properties of RAC [14, 16, 57].

3.2.Keyword analysis

Keyword analysis is an important work to depict the existing topics that have been focused within a given topic [58], such as RA in this study. According to van Eck and Waltman [34], the keyword network shows the knowledge, research themes, as well as their relationships and intellectual organizations. Adopting *VOSViewer* as the text-mining tool, the research team identified the most frequently studied "Author Keywords". These keywords had a minimum occurrence of *10*. Initially *74* out of totally *3,052* keywords were identified. General keywords such as "Recycled Aggregate" were removed from the keyword list. Other keywords with the consistent semantic meanings were combined, for example, RAC and "recycled aggregate concrete", RCA and "recycled concrete aggregate", etc. Several keywords were combined into a single keyword representing the same category. For instance, the original keywords including "Split Tensile Strength", "Compressive Strength", and "Mechanical Strength" were combined into "Mechanical". Ultimately a total of *38* keywords were selected for analysis.

Mechanical properties of RAC were the most frequently studied topic in RA-related research. RAC is the second most frequently studied keyword. It should be noticed that the third highest ranked keyword "Concrete" is different from RAC. RAC refers to the application of RA in the concrete mix design. "Concrete", on the other hand, could be either the source of RA or the application of RA. In other words, concrete exists across the life cycle stages of RA. It is found that LCA is another frequently studied topic in the RA domain. The highly occurring keywords (e.g., "Mechanical" and RAC) may not be the ones with highest average citations. It is inferred that HPC and LCA are the keywords with the highest influence to the research community of RA with their high average citations, followed by "Microstructure", "Durability", and "Shrinkage".

The keywords were divided into eight clusters in *VOSViewer*. Keywords in the same cluster are more likely to have mutual impacts of being cited by each other, for example, "Mechanical", "ITZ", and "Microstructure". Based on the visualization and quantitative measurements of mainstream keywords in RA, these following themes of research keywords can be summarized as below.

- Coarse RAs applied in concrete mix design and how they would affect the mechanical properties and microstructure of new concrete: examples of existing studies in this theme include but are not limited to Abreu et al. [59], Luo et al. [60], and Cantero et al. [61], etc;
- Fine RAs recycled and reused in cement composites (e.g., mortar): these studies also emphasized how the recycled fine RAs affected the performance of cement composites. Examples of studies adopting fine RAs in cement composite products can be found in Sosa et al. [62], Martínez-Aires et al. [63], Kim et al. [64], and Ho et al. [65];
- LCA approach in studying the sustainability of adopting RAs from C&D wastes: these studies may extend the engineering properties of recycled products (e.g., RAC) with a more comprehensive analysis of the environmental, social, and economical aspects of recycling wastes. Examples of these studies can be found in Marinković et al. [66], Rosado et al. [67], Hossain et al. [68], and Gan et al.[12];
- The effects of RAs on the fresh concrete properties, such as rheological properties in SCC [69, 70]: the workability [71, 72] of concrete containing RAs is a concern;
- The inter-relationship between creep/shrinkage [73] of RAC and the seismic performance of reinforced concrete structures [74]: seismic resistance of reinforced concrete structural members containing RAs has been gaining a momentum in the academic research in both numerical simulation and experimental studies, such as Liu et al. [75], and Ma et al. [76];

- The inferior properties of RAs due to its higher water absorption compared to NAs: studies [77, 78] have been focusing on improving the qualities of cement composites containing RAs. The nature and quality of RAs, as identified by Abdulla [79], could have significant impacts on RCA properties. Besides water absorption, the nature and quality of RAs also include their density[80], composition [49], as well as the waste treatment method [81];
- Adoptions of RA in pervious concrete [82, 83], and the effects of RAs on the permeability of RAC: to minimize the negative effects of the RA porosities, different sizes, sources, admixtures, and supplementary cementitious materials (SCMs) [84, 85] were considered in the mix design of pervious concrete;
- Durability of concrete containing RAs, including adopting RAs in HPC [86, 87]: the durability properties of HPC that have been studied in literature included permeability, resistance to carbonation, and resistance to chloride penetration [88, 89].

Besides these aforementioned RAC types, including pervious concrete, HPC, steel reinforced concrete structure, SCC, it should also be noticed that fiber-reinforced polymer (FRP) composite materials adopting RAs [90, 91] have also gained some increased attention in the academic community adopting RAs.

4. In-depth discussions

4.1.Mainstream research topics in recycled aggregates

Most studies from the literature sample focused on RAs from recycled C&D wastes, especially old concrete. Existing studies using RAs for a cleaner production were also mostly targeted on cement composites especially new concrete mixing and tests. Fig.2 demonstrates the typical micro-structure of RAs from crushed concrete observed under scanning electron microscope (SEM).

Aggregate
surface

Crack

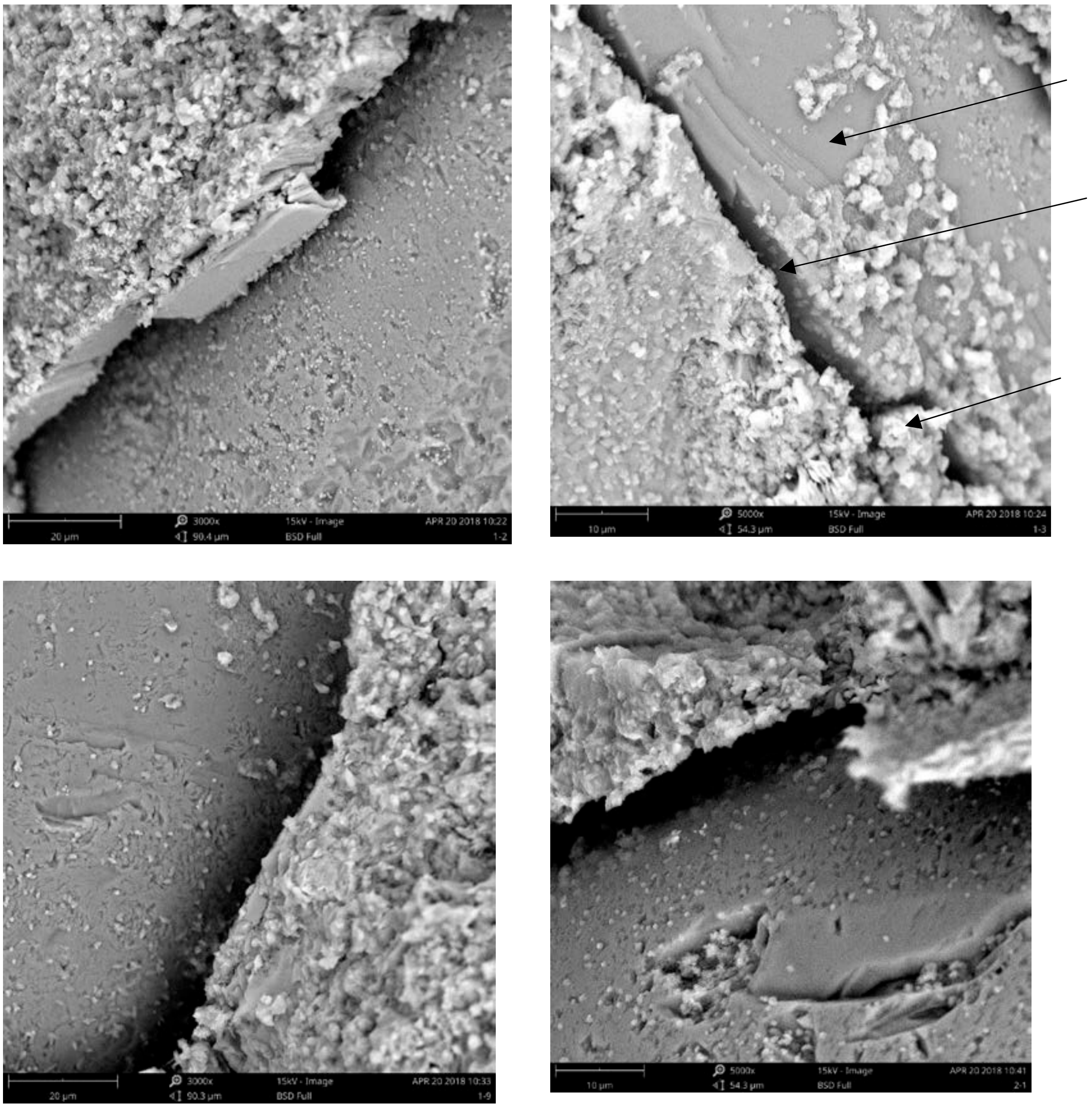

Fig.2. Microstructure of RAs from crushed concrete

It is seen in Fig.2 that RAs from recycled concrete generally have rough surface, cracking, and attached mortar. These micro-structural features could cause significant impacts on the engineering properties of cement composites containing RAs, for example, the mechanical behavior and durability of RAC. Several important studies demonstrating the influences of RAs on cement composites are showcased in Table 2.

Table 2. Studies investigating the influences of RAs on cement composites' properties

Study	**Type of RA**	**Mix design adopting RA**	**Cement composite properties tested**	**Applications of the cement composite containing RAs**	**Major findings**

Alexandridou et al. [49]	RA from different Greek recycling plants	0% , 25%, and 75% of coarse natural aggregates (NA) replaced by RA respectively	Compressive strength, concrete absorption, sorptivity, and carbonation resistance of RAC	Concrete specimens for the laboratory tests	The compressive strength of RAC ranged from significantly lower (37% reduction) than that of ordinary concrete. Clay minerals had a more adverse effect to concrete's strength. Higher water absorption of coarse RA was their most negative physical characteristic. Coarse RA reduced the durability of hardened concrete.
Dimitriou et al. [50]	Coarse RAs from different sources of crushed concrete	NA replaced by 50% and 100% of RA	Compressive strength, flexural strength, splitting tensile strength, modulus of elasticity, porosity, sorptivity, and permeability of RAC	Concrete specimens for the laboratory tests	Increasing the replacement ratio of RA to NA resulted in lower quality of RAC compared to normal concrete. Both mechanical and durability properties are negatively affected by the increase of the replacement ratio. But a simple treatment method to reduce the adhered mortar at RA surface could diminish the negative effects of RAs and create a better quality of RAC which could be competitive to normal concrete.
Ozbakkaloglu et al. [51]	Coarse RAs in two different sizes (i.e., 7 mm and 12 mm)	RAs used to replace NA at different replacement rates, including 0, 25%, 50%, and 100%	Compressive strength, elastic modulus, flexural strength, splitting tensile strength, workability, drying shrinkage, and water absorption of RAC	Specimens for testing, including cylinder specimens and prism specimens	An increase in the coarse aggregate size led to an increase in the 28-day elastic modulus and a decrease in the 28-day flexural and splitting tensile strengths. Coarser RA caused higher drying shrinkage and water absorption in concrete mix. RACs with up to 25% RA content exhibited slightly inferior mechanical and durability-related properties compared to the conventional concrete with the same compressive strength. But replacement of 100% NA would cause significant reductions in concrete properties.
Thomas et al. [92]	Fine and Coarse RAs from crushed test concrete specimens	20% of replacement of RA to the the coarse NA, and 100% replacement to both fine and coarse NAs	Compressive and tensile strength, permeability, water penetration, chloride penetration	Mortar and concrete specimens for the laboratory tests	The sulphur within RA did not significantly affect the mechanical or physical performance of mortar or RAC. But using RA from crushed concrete, with or without sulphur, was viable for the manufacture of recycled structural concretes for applications without

					exposure to high temperatures. The use of the fine fraction in RAs caused a significant loss of properties.
Etxeberria et al. [39]	Coarse RA from crushed concrete	Four different RAC produced, made with 0%, 25%, 50% and 100% of RA respectively	Compressive and tensile strength, modulus of elasticity of RAC	Concrete specimens for laboratory tests	Concrete crushed by an impact crusher achieves a high percentage of RAs without adhered mortar. Adhered mortar in RA caused the weak point in the RAC microstructure. RAC made with 100% of coarse RA had significantly lower compression strength than conventional concrete, or required more cement in mix design to achieve higher strength.
Evangelista and de Brito [41]	Fine RA from crushed concrete	Five different replacement ratios of fine RA to fine NA were adopted, namely 10%, 20%, 30%, 50%, and 100%	Compressive strength, split tensile strength, modulus of elasticity and abrasion resistance of RAC	Structural concrete specimens for laboratory tests	It was viable to produce concrete made with fine RA for structural concrete. Up to 30% replacement of fine RA to fine NA did not seem affecting the compressive strength of RAC. Both tensile splitting and modulus of elasticity were reduced with the increase of the replacement ratio. The abrasion resistance seemed to increase with the replacement of fine NA with fine RA.
Tam et al. [47]	RAs collected from local recycling plants, with sizes at 10mm and 20mm respectively	0%, 10%, 15%, 20%, 25% and 30% of RA was used to replace NA	Compressive strength of RAC specimens at different curing ages by using the normal mixing approach and the two-stage mixing approach	RAC specimens for laboratory tests	The two-stage mixing approach gives way for the cement slurry to gel up the RA, providing a stronger interfacial transition zone by filling up the cracks and pores within RA. This two-stage mixing approach can provide an effective method for enhancing the compressive strength and other mechanical performance of RAC.
Xiao et al. [40]	Coarse RA from waste concrete brought from runway	Replacement percentages of RA to NA at 0%, 30%, 50%, 70% and 100% respectively	Compressive strength, the elastic modulus, the peak and the ultimate strains of RAC	RAC specimens for laboratory tests	RAC specimens failed in a shear mode. The stress–strain curves of RAC indicated an increase in the peak strain and a significant decrease in the ductility. The compressive strength, elastic modulus of RAC generally decreased as the replacement ratio of RA increased. The peak strain of RAC also increased with the increase of RA contents.

Poon et al. [43]	Coarse RAs from two different type of crushed concrete, namely normal-strength concrete (NC), and high-performance Concrete (HPC)	Full replacement of NA by RA from NC, and RA from HPC respectively	Microstructure and compressive strength of RAC	RAC specimens for laboratory tests	RAC prepared with the RA from HPC developed higher compressive strength than RAC prepared with RA from NC at all tested ages. In particular, the strength of RAC prepared with the RA from HPC was comparable to that of conventional concrete. The difference in strength development between the RAC with HPC and with NC aggregates was due to the differences in both the strength of the coarse aggregates and the microstructural properties of the interfacial transition zones.
Poon et al. [45]	Coarse RA from crushed and graded unwashed concrete from a single source, sized at 10mm and 20mm	Various replacement ratios of RA to NA, were adaopted, namely 0%, 20%, 50%, and 100%; The moisture states of RAs were controlled at air-dried (AD), oven-dried (OD) and saturated surface-dried (SSD) states prior to use.	Slump and compressive strength of RAC	RAC specimens for laboratory tests	The moisture states of the RAs affected the change of slump of the fresh RAC. RA with OD led to a higher initial slump and quicker slump loss, while RAs with SSD and AD had normal initial slumps and slump losses. RAC from RA with AD exhibited the highest compressive strength. Aggregates in the AD state containing not more than 50% RA should be optimum for normal strength RAC production.

These influential studies showcased in Tables 1 and 2 could lead to further discussions below.

4.1.1. Engineering properties of cement composite materials adopting RAs

It is generally believed by the public that RAs would decrease concrete strength or lower other RAC properties. This could be due to their high porosity, internal cracking, high level of sulphate and chloride contents, high level of impurity and high cement mortar adhered to RAs [93]. This has been proved by many existing studies [47, 51, 94]. However, multiple studies showed that a moderate percentage of replacement of RA to NA could achieve comparable or even higher mechanical strength of concrete. This replacement percentage of RA to NA, as recommended in previous studies, generally ranges from 25% to 50% [95, 96]. A further mix design methodology was proposed by Pepe et al. [97] to predict the performance of RAC (e.g., compressive strength). Utilizing the positive effects of RAs for enhancing RAC properties was discussed extensively by Xu et al. [98], who proposed an optimized replacement percentage of RA to NA in concrete mix design, when the "internal curing" feature of RAs due to its porosities could compensate the inferior qualities of RAs. In order to improve the engineering properties and also to reduce carbon emissions, it is commonplace to adopt both RAs and SCMs (i.e., supplementary cementitious materials) in concrete mix design. For example, fly ash could enhance concrete workability when RA absorbs more moisture during concrete mixing [99]. These commonly adopted SCMs (e.g., fly ash) identified by Jin et al. [100] in commercial concrete production have been widely adopted together with RAs in sustainable concrete mix. Besides the addition of SCM and adding chemical admixture (e.g., superplasticizer) as suggested in existing studies [101, 102] to reduce the negative effects due to the water absorption of RAs, some pretreatment of RAs, such as removing impurities [103] and pre-wetting of RAs [104], could also be applied to to reduce the effects from the inferior properties of RAs.

4.1.2. The effect of RA sources on properties of recycled products

The effects of RA on concrete properties could be affected by multiple factors, such as its water absorption rate and chemical composition [49]. Chakradhara Rao [105] studied the effects of RAs coming from different parent concrete samples on RAC properties. It was found that RAs from the parent concrete would reduce the new concrete's compressive strength, but RAs from parent concrete with higher strength could result in comparable strength in the new concrete [105]. Kou and Poon [106] found that RAs from high-strength parent concrete (i.e., 80-100 MPa) samples could be used to produce high performance concrete with higher strength, lower drying shrinkage, and higher resistance to chloride ion penetration. The study from Kou and Poon [106] provided the guide of selecting proper parent concrete source to produce RA. However, how the higher strength of parent concrete would also produce higher quality of RA leading to better performance of RAC was not explained in-depth in most relevant existing studies [105, 106]. Despite that, it could be indicated from Lotfi et al. [107] that the quality of the parent concrete would affect the RAs' microstructure, which further impact RAs' engineering properties (e.g., water absorption, roughness, and abrasion resistance, etc). Jin et al. [104] compared two different types of RAs (i.e., RAs from demolished concrete and from recycled red bricks) in terms of their effects on concrete properties. It was found that the water absorption and hardness of RAs could cause differences in mechanical properties of RACs [47]. It was indicated by Poon et al. [43] that the RA from different parent concrete samples could affect the newly produced RAC's interfacial transition zones, which further affect the engineering properties of RAC. It was further suggested by Pepe et al. [103] that "cleaning" RAs to enhance their physical properties could reduce the performance gap between RAC and ordinary concrete. The "autogenous cleaning" of RAs, as described by Pepe et al. [103], referred to removal of surface impurities and reduction of particle heterogeneities.

4.1.3. Different types of RACs containing RAs

Ongoing research has been studying the feasibilities of adopting RAs in multiple types of RACs, including pervious concrete [82], reinforced concrete[108], SCC [69], FRP composites [109], and HPC [110]. Aslani et al. [111] optimized the mix design of high-performance SCC adopting RAs by testing the fresh and hardened properties. It was found that the proposed mix design could save cement amount up to *40%* [111]. Yan et al. [112] adopted flax FRP tube encased RAC to improve both the sustainability and the mechanical behavior of concrete specimens. Mechanical properties were also checked by adopting RAs in structural concrete.

For example, Gonzalez-Corominas et al. [113] found that a high performance recycled aggregate concrete could meet the structural requirements for prestressed concrete sleepers.

4.1.4. Sustainability effects of adopting RAs

Although most existing studies in RAs, as indicated in Table 3, have been focusing on the engineering properties of cement composites (especially concrete) containing RAs, other aspects of RA adoption such as economic factor [50] has also been concerned. Life cycle assessment (LCA) methods [114] have been developed to assess the impacts of adopting RAs, especially in comparing the environmental impacts between RAs and NAs based on available database and established inventory[115]. The sustainability effects of adopting RAs could be defined in a certain scope such as carbon dioxide (CO_2) emissions and energy consumption [116]. It was evaluated by Ding et al. [116] that the longer transportation distance for delivering NAs would make RAs an alternative option to lower environmental impact. Similarly, Colangelo et al. [117] adopted the LCA approach assisted by a computer simulation to demonstrate that RAs outperformed NAs in terms of environmental sustainability. It was further indicated that different types of RAs had variable sustainability impacts [117]. The LCA approach not only covers the cost and environmental effects by adopting RAs, but also affects policy making [118].

4.2.Research gaps in existing recycled aggregate studies

4.2.1. Sources of RAs

A review of the RA literature sample in this study reveals that the majority of RAs adopted for scholarly work come from C&D waste, especially demolished concrete [119]. Although C&D wastes from other building materials such as bricks [120], tiles [121], and ceramics [122] have also been studied as RA sources, significantly less research work has been performed to obtain RAs from other locally available sources. For example, oyster shells from food wastes in coastal cities could potentially be reused as RAs for new applications (e.g., building wall claddings).

Even within existing studies which adopted RAs from demolished concrete, the uncertainty on the source of the parent concrete could cause variability of RAs' engineering properties (e.g., water absorption), which would further lead to uncertainties in the RAC properties (e.g., mechanical strength and durability). Therefore, a comprehensive list of parameters that influence the RAC properties need to be established. As indicated in some existing studies [86, 123], these parameters could include the mix design of the parent concrete which further affects its strength, crushing method of the old concrete, and pretreatment of RAs. Most studies [105, 106] have been limited to the description of experimental findings of how the property of parent concrete would affect the RAC qualities. So far, there is still insufficient investigation from the material science perspective to explain how these parameters would affect RAC properties.

4.2.2. More engineering properties to be tested of cement composites containing RAs

More studies adopting RAs so far have been more focusing on RAC's performance in terms of traditionally defined properties such as mechanical properties [124] and durability [125]. There have been limited applications of RAs in being studied for their effects on other properties of RAC, such as environmental protection functions. For example, Xu et al. [98] stated that although there have been some ongoing studies of developing photocatalytic conventional concrete, not sufficient research had been performed to utilize the feature of RAs in the mix design of photocatalytic RAC. The internal pores and rough surface of RAs could become an advantage of RAC to capture photocatalysts (e.g., titanium dioxide or TiO_2) for air purification purpose [122]. The applications of RAs in building or infrastructure sectors are limited to non-structural members [126]. Developing RAs for a variety of engineering applications could be explored. RAs could also be tried with different cementitious materials in concrete mix design, e.g., grapheme oxide composites, as suggested by Xu et al. [31].

The literature sample from this study also indicates that there has been limited research investigating the performance of concrete structures containing RAs under fatigue or adverse outdoor environment. Assisted by Design Expert and Center Composite Design (CCD) software, Li et al. [127] found that fatigue and freeze-thaw cycles would influence the compressive strength and substantially impact the performance of pavement recycled aggregate concrete. Liu et al. [128] concluded that the RAs could enhance the fatigue life of rubber-modified recycled aggregate concrete (RRAC). Somewhat in contrast, the research of Peng et al. [129] showed that the fatigue life, residual strength, and residual stiffness of RAC all decreased with an increase in RA replacement percentage. Thomas et al. [130] also suggested that the use of RA reduced the ability of RAC to resist fatigue cycles. These existing studies of RAC did not reach completely consistent findings. Before extending RAs' application in practical engineering, the experimental and theoretical investigations need to continue in order to reveal more insightful findings regarding RAC or other composite structures' fatigue performance or their performance under adverse environment.

4.2.3. Recycled products adopting RAs

So far the majority of existing studies from this literature sample focused on RAC. Less attention has been paid to other cement composites (e.g., ready-mixed mortar), or other applications of RAs. The gap between scientific research and engineering practice can be found by reviewing the literature sample. For example, most of the studies have been focusing on the engineering properties of concrete containing RAs. However, the commonplace applications of RAs (e.g., from old concrete), could be largely limited to roadway construction, pavement sub-base, and backfilling according to several existing investigations [100, 131, 132]. The uncertainty of RA sources would cause problems of deciding the reapplication of RAs, as indicated by Oikonomou [133] and Meyer [134].

4.2.4. Enhancing the reuse rates of RAs

Crushed concrete for recycling and reuse could cause secondary wastes due to the fact that not all the sizes of RAs could be reused. Koshiro and Ichise [135] attempted to address this issue by adopting the entire waste reuse model through utilizing different sizes of RAs in cement composites (e.g., clay tiles). However, there have been so far limited studies addressing how RAs from different sources, sizes, and compositions could be efficiently utilized to enhance their reuse rate. It is common to see only part of the RAs from demolished buildings being reused in RAC production. There is a need to have standards, guidelines, or even legislations to specify the applications of RAs according to their qualities or properties. Technological applications to obtain this information of quality or property of RAs would become necessary.

4.2.5. A comprehensive indicator system of RA adoption

There has been insufficient research on a holistic evaluation of the impacts of adopting RAs. Existing studies may even come up with contradictory findings on the impacts. For example, Tam [136] and Gull [10] held different views on the cost-effectiveness on reusing RAs from C&D wastes. Factors contributing to the adoption between RAs and NAs include but are not limited to labor costs, available equipment, energy inputs, local availability, and reuse purpose (e.g., pavement). There is a need to develop a decision-making framework (e.g., an updated LCA approach) for stakeholders to evaluate the advantages and disadvantages of choosing RA and NA. Even though RAC containing RA could be improved by initial treatment of RAs, the practical feasibility of procedures to remove impurities (e.g., Tam et al [47]) in RA surfaces needs to be investigated, especially considering other factors such as labor and cost.

4.3.Suggestions for enhancing RA adoption as sustainable construction materials

The mainstream research topics in RAs and research limitations based on the scientometric review of this literature sample indicate the interdisciplinary nature of adopting RAs for the cleaner production in the construction industry. The industry is causing a significant impact on the living environment based on the facts that: (1) it consumes a tremendous amount of natural resources (e.g., NAs); (2) it contributes a significant portion of the carbon emission crossing industries; and (3) it generates an overwhelming amount of C&D wastes causing shortages of urban landfill space. The concept of cleaner production has been practiced for a few decades and participating companies had shown some positive results in terms of material utilization, lowered energy consumptions and reduced carbon emissions [11]. Implementation of the cleaner production involves technological evolvement, business models, and public awareness as indicated from existing studies [69, 137]. This has been somehow reflected in adopting RA in the construction sector. For example, Jin et al. [126] provided the workflow in the production line of using RAs from crushed C&D wastes to manufacture masonry bricks. Consistent with the discussion provided by Kjaerheim [11], it was further inferred that the adoption of cleaner production needs multiple driving factors, such as governmental policy, social acceptance, and the market condition [126, 131].

A review of existing literature [11, 138, 139] indicates that LCA has been a commonly adopted modeling approach in evaluating the outcomes of implementing sustainability. In the context of utilizing wastes in the construction sector, LCA has been implemented to quantify the environmental and technical effects of RA adoption [140, 141]. Based on the existing studies of promoting cleaner production practice, as well as research on reusing RAs, suggestions to enhance RA utilization to improve the sustainability are proposed herein:

- Information tracking system can be developed for sources of RAs in order to determine its application. Sources of RAs could cause different engineering properties to new cement composites as indicated from previous research [142, 143]. The information system of RAs could include but be not limited to its parent concrete mechanical strength, building type, and laboratory test results, etc.

- More site investigation and trail projects can be conducted for investigating the engineering properties and new applications of construction products containing RAs. For example, precast concrete members, as one type of off-site construction components, can be tested of its resistance to natural disasters when RAs are adopted in its mix design. The applications of RA in building construction could be more than just non-structural members. For example, Japanese Industrial Standards [144, 145] provide some guides on the classes of RAs to be applied in different types of concrete structures. A variety of applications for RA-based construction products can also bridge the gap between scientific research community and industry practice.
- Local availability and regional contexts should be considered for adopting RAs. Stakeholders including policy makers, industry practitioners, and academic researchers could promote the local "green" production by looking at regionally available waste sources beyond the construction industry. For example, sea animal shells from food wastes could be potentially recyclable resources to produce RAs in coastal areas. Agricultural regions might also consider reusing local by-products for RA as indicated by Eziefula [22].
- Reusing these local wastes for productions of RAs should not be limited to C&D wastes, but across industries. A comprehensive evaluation of the social, economic, technical, and environmental indicators for adopting a certain type of RAs would be necessary. This evaluation system, based on the life cycle assessment of RAs, should support the decision making for not only whether or not to adopt a certain type of RA (e.g., RA from oyster shells), but also for how to optimize its reuse and application. For example, oyster shells may not only be used for coarse RAs in concrete production, but also as fine RAs for wall finish or decoration.

- Determining the multiple uses of the same type of RA, or RA from mixed sources of wastes (e.g., C&D waste) in order to enhance the reuse rate. It is important to minimize the "secondary waste" generated by producing RAs from wastes. For example, fine particles would become "secondary waste" if only coarse RAs are utilized from crushing C&D wastes. Fine RAs could also be potentially applied in construction (e.g., mortar).
- Finally, public awareness towards building products containing RAs can be raised to embrace the sustainability culture. The public might have a biased opinion towards recycled products, but the mindset could be changed when they gain more knowledge of properties of products containing RAs [126]. Pilot construction projects or a prototype of building product such as Waste House [146] works a bridge between multiple stakeholders, including researchers, industry practitioners, and the general public.

4.4.Research directions for recycled aggregate

Following the summaries of mainstream research topics, gaps from existing RA studies, and suggestions to enhance RA adoption, the research framework in the RA domain is proposed in Fig.3. The existing research topics in Fig.3 are generated based on the prior scientometric analysis of keywords, for example, mechanical properties of new concrete containing RAs.

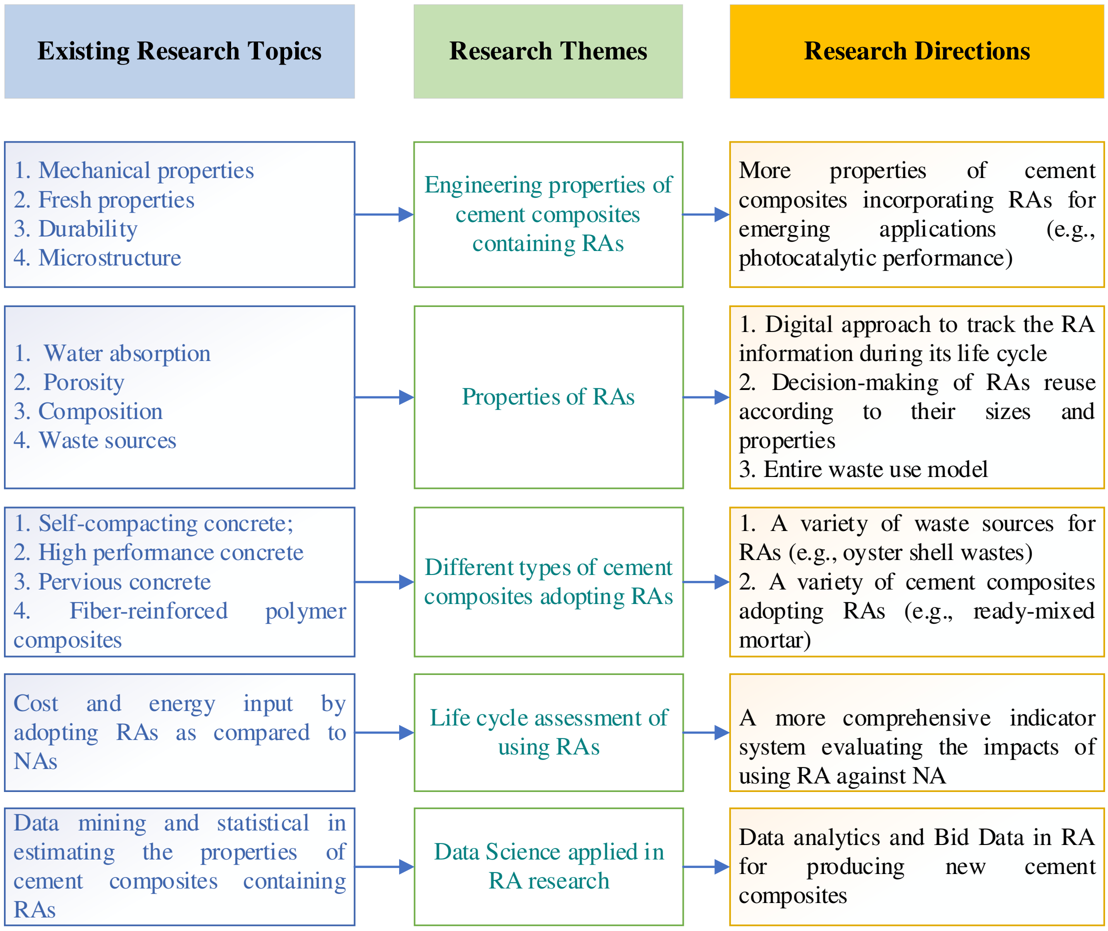

Fig.3. Research framework linking the existing research topics in RA to future research directions

Five main themes are suggested in Fig.3 in the RA domain, linking the existing research topics into future directions:

- Depending on the application of RAs, more engineering properties of RAs and a variety of RACs could be developed. For example, applying RAs in photocatalytic pervious concrete pavements for absorbing air pollutant particles. As suggested by Xu et al. [98], RAs have their advantage of being more capable to absorb more photocatalysts for developing environmentally friendly concrete.
- Besides the properties of RAs themselves listed in Fig.3 such as water absorption, the waste treatment method is a key factor that affects the properties of RAs, and further influences the properties of recycled products, as indicated from existing studies [81, 147]. A digital

platform, such as Building Information Modeling (BIM) and Geographic Information Systems (GIS), could be adopted to identify or track the information (e.g., source) of RAs before being applied. This information of RAs would be important for deciding how to reuse the RAs (e.g., in non-structural building elements). Information tracked from the source of RAs would also be useful to analyze the heterogeneous compositions of wastes in order to enhance the reuse rate of RAs.

- The source of RAs and the application of RAs could be extended to other industries beyond the construction field. Depending on local availability, more sources of RAs could be identified besides the C&D sites, for example, various types of industrial wastes as introduced by de Brito and Saikia [148]. GIS, as the information tool which has been applied in the C&D waste treatment [149], could also be further developed in locating potential sources of RAs and their applications, which may not be limited to cement composites but also geotechnical and road pavement materials [150].
- Digital approach to track the property information of RA throughout its life cycle including its early stages [151] could be further developed. For example, during the design stage of a concrete structure building, the amount of RAs in different sizes for reuse could be estimated and stored as information in the BIM platform. The properties of RAs would be critical for applications in structural concrete especially from the life cycle perspective [152]
- A more comprehensive sustainability indicator system for adopting RAs against NAs could be developed by considering and weighting social, economical, environmental, and engineering aspects.
- The existing data mining and Big Data approach [153] could be applied in estimating properties of new cement composites containing RAs, for example, the Analytical Systemization Method newly developed by Obe et al [150] in building the data-matrix for applying RAs. The properties of cement composites should not be limited to mechanical

properties [154]. More properties of cement composites adopting RAs such as durability could be evaluated using data analytics methods as suggested by Koo et al. [55].

5. Conclusion

This study extends the concept of Circular Economy by focusing on recycled aggregate (RA) as the vehicle to bridge construction and demolition (C&D) wastes and their applications during its life cycle. A comprehensive review of existing literature based on the sample of *1,639* journal articles was conducted to provide the big picture of the existing research status in RAs, to discuss limitations in adopting RAs, as well as providing visions for future research in RAs. The current study contributes to the body of knowledge in adopting RA as sustainable construction materials based on the fact that the source of RA should not be limited to C&D wastes, and the application of RA could be more than cement composites.

A holistic review approach consisting of three steps, namely bibliometric literature search, text-mining-based scientometric analysis, and in-depth qualitative discussion, was adopted as the research methodology. This holistic review methodology could be further adapted to assist the review of other research domains. Major findings generated following this review methodology can be summarized below.

5.1. Findings from scientometric analysis

Major findings from scientometric analysis are summarized below:

- Most existing research focused on adopting RAs in the studies of new concrete production, with mechanical properties of recycled aggregate concrete as the most frequently studied topic in RA.
- Articles with most citations were published in earlier years and focused on mechanical properties of cement composites containing RAs. Articles with highest normalized citations

were published in more recent years and focused on review work, durability of recycled aggregate concrete, and applying computing and modeling methods.

5.2.The interrelationship between the scientometric analysis results and RA as sustainable construction materials

Following the scientometric analysis, this study summarized the mainstream research topics in existing literature of RA, identified the gaps of existing studies, and provided suggestions for enhancing RA usage. Existing research topics have been largely focusing on adopting RAs from C&D wastes, applying RAs in concrete mix, and testing the engineering properties of concrete containing RAs. A variety of concrete types had been studied, including high-performance concrete, self-compacting concrete, fiber-reinforced polymer composites, and pervious concrete. Life-cycle assessment approach had been applied in comparing the environmental effects between RAs and natural aggregates. Limitations of these existing studies were identified and discussed, including:

- the need to explore more engineering properties of cement composites containing RAs beyond mechanical behaviour and durability, such as photocatalytic concrete for air purification purpose;
- the need to have a variety of RA sources beyond C&D wastes;
- the need to enhance the reuse rate of RAs from C&D wastes;
- the necessity of having a variety of RA applications, such as ready-mixed mortar;
- academic studies of RA applications to bridge the gap between experimental research and industry practice, such as the composite structure's fatigue performance;
- a comprehensive indicator system to evaluate the sustainability of RA adoption.

Barriers in adopting RA to embrace the cleaner production in the real world were discussed among the research team, specifically: (1) uncertainty of waste sources for decision making of proper application of RA in the construction industry; (2) lack of a comprehensive evaluation of the properties of building products containing wastes; (3) limited applications of recycled products; (4) the gap between academic research and industry practice of reusing RAs; (5) insufficiently developed indicator system for decision making in adopting RAs. Corresponding suggestions were provided addressing these existing barriers to promote the RA usage in the construction sector, including: (1) an information tracking system to be developed to reduce the risks of using RAs associated with its source uncertainty; (2) more site tests and investigations to explore engineering properties of construction products adopting RAs; (3) multi-stakeholder involvement in evaluating the proper type of RAs in the local context; (4) a cross-industry vision to identify appropriate sources of RAs; (5) minimizing the "secondary wastes" in the process of producing RAs; and (6) nurturing a sustainability culture by demonstrating more pilot projects or prototypes to the public.

5.3. Research framework guiding future research directions in RA

Finally, a research framework was proposed to link existing research topics to recommended future research directions:

- more engineering properties of cement composites to be explored depending on the RA applications;
- information tools to be developed to track the source and quality of RAs;
- digital methods to obtain the RA information throughout its life cycle;
- a more comprehensive sustainability indicator system for adopting RAs against natural aggregates;
- data analytics methods applied in estimating more properties of cement composites containing RAs.

To move the academic research work forward, researchers in this study suggest that the scholarly work of adopting RAs should not be limited to engineering properties of cement composites containing RAs, but also a variety of RA sources, varied RA applications, as well as interdisciplinary research incorporating data science, digital technologies, policy making, and a comprehensive sustainability assessment in promoting RA research and practice.

5.4. *Research limitations*

This review-based study is limited to the English journal articles indexed in *Scopus*. It excludes articles published in other languages and also other types of published resources such as trade magazine. The literature sample in this study was limited to academic journal articles. Another review focusing on latest industry practice from other reference sources (e.g., trade magazines) focusing on RAs in would be useful to further identify the gap between academic research and industry practice.

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References

[1] P. Ghisellini, C. Cialani, S. Ulgiati, A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems, J. Clean. Prod. 114 (2016) 11-32.
[2] D. Ness, Sustainable urban infrastructure in China: Towards a Factor 10 improvement in resource productivity through integrated infrastructure systems, Int. J. Sustainable Dev. World Ecol. 15(4) (2008) 288-301.
[3] F. Preston, A Global Redesign? Shaping the Circular Economy. Briefing Paper. Available: http://www.chathamhouse.org/sites/default/files/public/Research/Energy%20Environment%20and%20Development/bp0312_preston.pdf. (accessed on 1 Nov 2018). (2012).
[4] G. Rodríguez, C. Medina, F.J. Alegre, E. Asensio, M.I. De Sánchez Rojas, Assessment of Construction and Demolition Waste plant management in Spain: In pursuit of sustainability and eco-efficiency, J. Clean. Prod. 90 (2015) 16-24.
[5] H. Duan, J. Li, Construction and demolition waste management: China's lessons, Waste Manage. Res. 34(5) (2016) 397-398.
[6] J. Hana, J.K. Thakur, Sustainable roadway construction using recycled aggregates with geosynthetics, Sustainable Cities Soc. 14(1) (2015) 342-350.

[7] R. Jin, H. Yuan, Q. Chen, Science mapping approach to assisting the review of construction and demolition waste management research published between 2009 and 2018, Resour. Conserv. Recycl. 140 (2019) 175-188.
[8] D. Pedro, J. de Brito, L. Evangelista, Mechanical characterization of high performance concrete prepared with recycled aggregates and silica fume from precast industry, J. Clean. Prod. 164 (2017) 939-949.
[9] M.F. Alnahhal, U.J. Alengaram, M.Z. Jumaat, F. Abutaha, M.A. Alqedra, R.R. Nayaka, Assessment on engineering properties and CO2 emissions of recycled aggregate concrete incorporating waste products as supplements to Portland cement, J. Clean. Prod. 203 (2018) 822-835.
[10] I. Gull, Testing of strength of recycled waste concrete and its applicability, J Constr Eng Manage 137(1) (2011) 1-5.
[11] G. Kjaerheim, Cleaner production and sustainability, J. Clean. Prod. 13(4) (2005) 329-339.
[12] V.J.L. Gan, J.C.P. Cheng, I.M.C. Lo, Integrating life cycle assessment and multi-objective optimization for economical and environmentally sustainable supply of aggregate, J. Clean. Prod. 113 (2016) 76-85.
[13] M.U. Hossain, C.S. Poon, Y.H. Dong, I.M.C. Lo, J.C.P. Cheng, Development of social sustainability assessment method and a comparative case study on assessing recycled construction materials, Int. J. Life Cycle Assess. 23(8) (2018) 1654-1674.
[14] N. Kisku, H. Joshi, M. Ansari, S.K. Panda, S. Nayak, S.C. Dutta, A critical review and assessment for usage of recycled aggregate as sustainable construction material, Constr Build Mater 131 (2017) 721-740.
[15] M. Chakradhara Rao, Bhattacharyya S.K., Barai S.V., , Systematic Approach of Characterisation and Behaviour of Recycled Aggregate Concrete, Springer Nature (2019).
[16] M. Behera, S.K. Bhattacharyya, A.K. Minocha, R. Deoliya, S. Maiti, Recycled aggregate from C&D waste & its use in concrete - A breakthrough towards sustainability in construction sector: A review, Constr Build Mater 68 (2014) 501-516.
[17] Z. Chen, J. Xu, Y. Chen, E.M. Lui, Recycling and reuse of construction and demolition waste in concrete-filled steel tubes: A review, Constr Build Mater 126 (2016) 641-660.
[18] X. Li, Recycling and reuse of waste concrete in China. Part II. Structural behaviour of recycled aggregate concrete and engineering applications, Resour. Conserv. Recycl. 53(3) (2009) 107-112.
[19] R.V. Silva, J. de Brito, R.K. Dhir, Fresh-state performance of recycled aggregate concrete: A review, Constr Build Mater 178 (2018) 19-31.
[20] H. Guo, C. Shi, X. Guan, J. Zhu, Y. Ding, T.C. Ling, H. Zhang, Y. Wang, Durability of recycled aggregate concrete – A review, Cem Concr Compos 89 (2018) 251-259.
[21] V.W.Y. Tam, M. Soomro, A.C.J. Evangelista, A review of recycled aggregate in concrete applications (2000–2017), Constr Build Mater 172 (2018) 272-292.
[22] U.G. Eziefula, Developments in utilisation of agricultural and aquaculture by-products as aggregate in concrete–a review, Environ. Technol. Rev. 7(1) (2018) 19-45.
[23] S.H. Eo, S.T. Yi, Effect of oyster shell as an aggregate replacement on the characteristics of concrete, Mag Concr Res 67(15) (2015) 833-842.
[24] F. Agrela, M.G. Beltran, M. Cabrera, M. López, J. Rosales, J. Ayuso, Properties of Recycled Concrete Manufacturing with All-in Recycled Aggregates and Processed Biomass Bottom Ash, Waste Biomass Valoris. 9(7) (2018) 1247-1259.
[25] K. Muthusamy, N. Nordin, G. Vesuvapateran, M. Ali, N.A. Mohd Annual, H. Harun, H. Ullap, Exploratory study of rubber seed shell as partial coarse aggregate replacement in concrete, Research Journal of Applied Sciences, Engineering and Technology 7(6) (2014) 1013-1016.
[26] M.A. Abdoli, A. Fathollahi, R. Babaei, The application of recycled aggregates of construction debris in asphalt concrete mix design, Int. J. Environ. Res. 9(2) (2015) 489-494.
[27] A. Arulrajah, M.M.Y. Ali, M.M. Disfani, S. Horpibulsuk, Recycled-glass blends in pavement base/subbase applications: Laboratory and field evaluation, J Mater Civ Eng 26(7) (2014).
[28] S.Y. Abate, K.I. Song, J.K. Song, B.Y. Lee, H.K. Kim, Internal curing effect of raw and carbonated recycled aggregate on the properties of high-strength slag-cement mortar, Constr Build Mater 165 (2018) 64-71.
[29] J. Song, H. Zhang, W. Dong, A review of emerging trends in global PPP research: analysis and visualization, Scientometrics 107(3) (2016) 1111-1147.
[30] M.R. Hosseini, I. Martek, E.K. Zavadskas, A.A. Aibinu, M. Arashpour, N. Chileshe, Critical evaluation of off-site construction research: A Scientometric analysis, Autom Constr 87 (2018) 235-247.
[31] Y. Xu, J. Zeng, W. Chen, R. Jin, B. Li, Z. Pan, A holistic review of cement composites reinforced with graphene oxide, Constr Build Mater 171 (2018) 291-302.
[32] R. Jin, P.X.W. Zou, P. Piroozfar, H. Wood, Y. Yang, L. Yan, Y. Han, A science mapping approach based review of construction safety research, Saf. Sci. 113 (2019) 285-297.

[33] Q. He, G. Wang, L. Luo, Q. Shi, J. Xie, X. Meng, Mapping the managerial areas of Building Information Modeling (BIM) using scientometric analysis, International Journal of Project Management 35(4) (2017) 670-685.
[34] N.J. Van Eck, L. Waltman, Visualizing bibliometric networks. . In Y. Ding, R. Rousseau, & D. Wolfram (Eds.), Measuring scholarly impact: Methods and practice, 285–320, (2014).
[35] L. Tang, Q. Shen, E.W.L. Cheng, A review of studies on Public-Private Partnership projects in the construction industry, International Journal of Project Management 28(7) (2010) 683-694.
[36] X. Zhao, A scientometric review of global BIM research: Analysis and visualization, Autom Constr 80 (2017) 37-47.
[37] A. Aghaei Chadegani, H. Salehi, M.M. Md Yunus, H. Farhadi, M. Fooladi, M. Farhadi, N. Ale Ebrahim, A comparison between two main academic literature collections: Web of science and scopus databases, Asian Soc. Sci. 9(5) (2013) 18-26.
[38] N.J. van Eck, L. Waltman, VOSviewer Manual. Manual for VOSviewer version 1.6.6. , (2017).
[39] M. Etxeberria, E. Vázquez, A. Marí, M. Barra, Influence of amount of recycled coarse aggregates and production process on properties of recycled aggregate concrete, Cem Concr Res 37(5) (2007) 735-742.
[40] J. Xiao, J. Li, C. Zhang, Mechanical properties of recycled aggregate concrete under uniaxial loading, Cem Concr Res 35(6) (2005) 1187-1194.
[41] L. Evangelista, J. de Brito, Mechanical behaviour of concrete made with fine recycled concrete aggregates, Cem Concr Compos 29(5) (2007) 397-401.
[42] K.K. Sagoe-Crentsil, T. Brown, A.H. Taylor, Performance of concrete made with commercially produced coarse recycled concrete aggregate, Cem Concr Res 31(5) (2001) 707-712.
[43] C.S. Poon, Z.H. Shui, L. Lam, Effect of microstructure of ITZ on compressive strength of concrete prepared with recycled aggregates, Constr Build Mater 18(6) (2004) 461-468.
[44] A. Katz, Properties of concrete made with recycled aggregate from partially hydrated old concrete, Cem Concr Res 33(5) (2003) 703-711.
[45] C.S. Poon, Z.H. Shui, L. Lam, H. Fok, S.C. Kou, Influence of moisture states of natural and recycled aggregates on the slump and compressive strength of concrete, Cem Concr Res 34(1) (2004) 31-36.
[46] M.S. de Juan, P.A. Gutiérrez, Study on the influence of attached mortar content on the properties of recycled concrete aggregate, Constr Build Mater 23(2) (2009) 872-877.
[47] V.W.Y. Tam, X.F. Gao, C.M. Tam, Microstructural analysis of recycled aggregate concrete produced from two-stage mixing approach, Cem Concr Res 35(6) (2005) 1195-1203.
[48] A. Ajdukiewicz, A. Kliszczewicz, Influence of recycled aggregates on mechanical properties of HS/HPC, Cem Concr Compos 24(2) (2002) 269-279.
[49] C. Alexandridou, G.N. Angelopoulos, F.A. Coutelieris, Mechanical and durability performance of concrete produced with recycled aggregates from Greek construction and demolition waste plants, J. Clean. Prod. 176 (2018) 745-757.
[50] G. Dimitriou, P. Savva, M.F. Petrou, Enhancing mechanical and durability properties of recycled aggregate concrete, Constr Build Mater 158 (2018) 228-235.
[51] T. Ozbakkaloglu, A. Gholampour, T. Xie, Mechanical and durability properties of recycled aggregate concrete: Effect of recycled aggregate properties and content, J Mater Civ Eng 30(2) (2018).
[52] E.M. Golafshani, A. Behnood, Application of soft computing methods for predicting the elastic modulus of recycled aggregate concrete, J. Clean. Prod. 176 (2018) 1163-1176.
[53] Z. Hu, L.X. Mao, J. Xia, J.B. Liu, J. Gao, J. Yang, Q.F. Liu, Five-phase modelling for effective diffusion coefficient of chlorides in recycled concrete, Mag Concr Res 70(11) (2018) 593-594.
[54] R. Jin, Q. Chen, A.B.O. Soboyejo, Non-linear and mixed regression models in predicting sustainable concrete strength, Constr Build Mater 170 (2018) 142-152.
[55] C. Koo, R. Jin, B. Li, S.H. Cha, D. Wanatowski, Case-based reasoning approach to estimating the strength of sustainable concrete, Comput. Concr. 20(6) (2017) 645-654.
[56] B.A. Omran, Q. Chen, R. Jin, Comparison of Data Mining Techniques for Predicting Compressive Strength of Environmentally Friendly Concrete, J. Comput. Civ. Eng. 30(6) (2016).
[57] J. Xiao, W. Li, Y. Fan, X. Huang, An overview of study on recycled aggregate concrete in China (1996-2011), Constr Build Mater 31 (2012) 364-383.
[58] H.N. Su, P.C. Lee, Mapping knowledge structure by keyword co-occurrence: A first look at journal papers in Technology Foresight, Scientometrics 85(1) (2010) 65-79.
[59] V. Abreu, L. Evangelista, J. de Brito, The effect of multi-recycling on the mechanical performance of coarse recycled aggregates concrete, Constr Build Mater 188 (2018) 480-489.

[60] S. Luo, S. Ye, J. Xiao, J. Zheng, Y. Zhu, Carbonated recycled coarse aggregate and uniaxial compressive stress-strain relation of recycled aggregate concrete, Constr Build Mater 188 (2018) 956-965.
[61] B. Cantero, I.F. Sáez del Bosque, A. Matías, C. Medina, Statistically significant effects of mixed recycled aggregate on the physical-mechanical properties of structural concretes, Constr Build Mater 185 (2018) 93-101.
[62] M.E. Sosa, L.E. Carrizo, C.J. Zega, Y.A. Villagrán Zaccardi, Water absorption of fine recycled aggregates: effective determination by a method based on electrical conductivity, Mater Struct 51(5) (2018).
[63] M.D. Martínez-Aires, M. López-Alonso, M. Martínez-Rojas, Building information modeling and safety management: A systematic review, Saf. Sci. 101 (2018) 11-18.
[64] H.S. Kim, J.M. Kim, B. Kim, Quality improvement of recycled fine aggregate using steel ball with the help of acid treatment, J. Mater. Cycles Waste Manage. 20(2) (2018) 754-765.
[65] H.L. Ho, R. Huang, W.T. Lin, A. Cheng, Pore-structures and durability of concrete containing pre-coated fine recycled mixed aggregates using pozzolan and polyvinyl alcohol materials, Constr Build Mater 160 (2018) 278-292.
[66] S. Marinković, J. Dragaš, I. Ignjatović, N. Tošić, Environmental assessment of green concretes for structural use, J. Clean. Prod. 154 (2017) 633-649.
[67] L.P. Rosado, P. Vitale, C.S.G. Penteado, U. Arena, Life cycle assessment of natural and mixed recycled aggregate production in Brazil, J. Clean. Prod. 151 (2017) 634-642.
[68] M.U. Hossain, C.S. Poon, I.M.C. Lo, J.C.P. Cheng, Comparative environmental evaluation of aggregate production from recycled waste materials and virgin sources by LCA, Resour. Conserv. Recycl. 109 (2016) 67-77.
[69] I. González-Taboada, B. González-Fonteboa, F. Martínez-Abella, S. Seara-Paz, Evaluation of self-compacting recycled concrete robustness by statistical approach, Constr Build Mater 176 (2018) 720-736.
[70] N. Singh, S.P. Singh, Carbonation resistance of self-compacting recycled aggregate concretes with silica fume, J. Sustain. Cem. Based Mater. 7(4) (2018) 214-238.
[71] I. González-Taboada, B. González-Fonteboa, J. Eiras-López, G. Rojo-López, Tools for the study of self-compacting recycled concrete fresh behaviour: Workability and rheology, J. Clean. Prod. 156 (2017) 1-18.
[72] M.B. Leite, J.G.L. Figueire Do Filho, P.R.L. Lima, Workability study of concretes made with recycled mortar aggregate, Mater Struct 46(10) (2013) 1765-1778.
[73] Y. Geng, Y. Wang, J. Chen, Creep behaviour of concrete using recycled coarse aggregates obtained from source concrete with different strengths, Constr Build Mater 128 (2016) 199-213.
[74] H. Lingard, N. Blismas, J. Harley, A. Stranieri, R.P. Zhang, P. Pirzadeh, Making the invisible visible Stimulating work health and safety-relevant thinking through the use of infographics in construction design, Eng. Constr. Archit. Manage. 25(1) (2018) 39-61.
[75] W. Liu, W. Cao, J. Zhang, Q. Qiao, H. Ma, Seismic performance of composite shear walls constructed using recycled aggregate concrete and different expandable polystyrene configurations, Mater. 9(3) (2016).
[76] H. Ma, J. Xue, Y. Liu, J. Dong, Numerical analysis and horizontal bearing capacity of steel reinforced recycled concrete columns, Steel Compos. Struct. 22(4) (2016) 797-820.
[77] S.H. Adnan, A. Omar, Improvement of the compressive strength and water absorption of recycled aggregate concrete by using uncontrolled burnt rice husk ash, ARPN J. Eng. Appl. Sci. 11(3) (2016) 1504-1509.
[78] A. Mwasha, R. Ramnath, Manufacturing concrete with high compressive strength using recycled aggregates, J Mater Civ Eng 30(8) (2018).
[79] N.A. Abdulla, Effect of recycled coarse aggregate type on concrete, J Mater Civ Eng 27(10) (2015).
[80] C.J. Molineux, C.H. Fentiman, A.C. Gange, Characterising alternative recycled waste materials for use as green roof growing media in the U.K, Ecol. Eng. 35(10) (2009) 1507-1513.
[81] J.J. de Oliveira Andrade, M.C. Wenzel, G.H. da Rocha, S.R. da Silva, Performance of rendering mortars containing sludge from water treatment plants as fine recycled aggregate, J. Clean. Prod. 192 (2018) 159-168.
[82] P.W. Barnhouse, W.V. Srubar, III, Material characterization and hydraulic conductivity modeling of macroporous recycled-aggregate pervious concrete, Constr Build Mater 110 (2016) 89-97.
[83] S. Deepika, K. Lalithanjali, M.R. Ponmalar, B. Vinushitha, T. Manju, Influence of recycled aggregate based pervious concrete with flyash, Int. J. ChemTech Res. 7(6) (2014) 2648-2653.
[84] R. Sriravindrarajah, N.D.H. Wang, L.J.W. Ervin, Mix Design for Pervious Recycled Aggregate Concrete, Ind. J. Concr. Struct. Mater. 6(4) (2012) 239-246.
[85] V.A. Ulloa-Mayorga, M.A. Uribe-Garcés, D.P. Paz-Gómez, Y.A. Alvarado, B. Torres, I. Gasch, Performance of pervious concrete containing combined recycled aggregates, Ingen. Invest. 38(2) (2018) 34-41.

[86] V. Afroughsabet, L. Biolzi, T. Ozbakkaloglu, Influence of double hooked-end steel fibers and slag on mechanical and durability properties of high performance recycled aggregate concrete, Compos. Struct. 181 (2017) 273-284.
[87] M. Etxeberria, A. Gonzalez-Corominas, The assessment of ceramic and mixed recycled aggregates for high strength and low shrinkage concretes, Mater Struct 51(5) (2018).
[88] S.M. Kalaiarasu, K. Subramanian, Properties of recycled aggregate concrete with silica fume, J. Appl. Sci. 6(14) (2006) 2956-2958.
[89] P. Rattanachu, I. Karntong, W. Tangchirapat, C. Jaturapitakkul, P. Chindaprasirt, Influence of bagasse ash and recycled concrete aggregate on hardened properties of high-strength concrete, Mater. Constr. 68(330) (2018).
[90] J. Zheng, T. Ozbakkaloglu, Sustainable FRP–recycled aggregate concrete–steel composite columns: Behavior of circular and square columns under axial compression, Thin-Walled Struct 120 (2017) 60-69.
[91] C. Gao, L. Huang, L. Yan, B. Kasal, W. Li, Behavior of glass and carbon FRP tube encased recycled aggregate concrete with recycled clay brick aggregate, Compos. Struct. 155 (2016) 245-254.
[92] C. Thomas, A. Cimentada, J.A. Polanco, J. Setién, D. Méndez, J. Rico, Influence of recycled aggregates containing sulphur on properties of recycled aggregate mortar and concrete, Compos Part B: Eng 45(1) (2013) 474-485.
[93] J.S. Ryu, An experimental study on the effect of recycled aggregate on concrete properties, Mag Concr Res 54(1) (2002) 7-12.
[94] H.E. Opara, U.G. Eziefula, C.C. Ugwuegbu, Experimental study of concrete using recycled coarse aggregate, Int. J. Mater. Struct. Integrity 10(4) (2016) 123-132.
[95] S.F.U. Ahmed, Properties of concrete containing construction and demolition wastes and fly ash, J Mater Civ Eng 25(12) (2013) 1864-1870.
[96] M. Limbachiya, M. Seddik Meddah, Y. Ouchagour, Performance of portland/silica fume cement concrete produced with recycled concrete aggregate, ACI Mater J 109(1) (2012) 91-100.
[97] M. Pepe, R.D. Toledo Filho, E.A.B. Koenders, E. Martinelli, A novel mix design methodology for Recycled Aggregate Concrete, Constr Build Mater 122 (2016) 362-372.
[98] Y. Xu, W. Chen, R. Jin, J. Shen, K. Smallbone, C. Yan, L. Hu, Experimental investigation of photocatalytic effects of concrete in air purification adopting entire concrete waste reuse model, J. Hazard. Mater. 353 (2018) 421-430.
[99] R. Purushothaman, R.R. Amirthavalli, L. Karan, Influence of treatment methods on the strength and performance characteristics of recycled aggregate concrete, J Mater Civ Eng 27(5) (2015).
[100] R. Jin, Q. Chen, Investigation of Concrete Recycling in the U.S. Construction Industry, International Conference on Sustainable Design, Engineering and Construction, ICSDEC 2015, Elsevier Ltd, 2015, pp. 894-901.
[101] M. Bravo, J. de Brito, L. Evangelista, J. Pacheco, Superplasticizer's efficiency on the mechanical properties of recycled aggregates concrete: Influence of recycled aggregates composition and incorporation ratio, Constr Build Mater 153 (2017) 129-138.
[102] Z. Pan, J. Zhou, X. Jiang, Y. Xu, R. Jin, J. Ma, Y. Zhuang, Z. Diao, S. Zhang, Q. Si, W. Chen, Investigating the effects of steel slag powder on the properties of self-compacting concrete with recycled aggregates, Constr Build Mater 200 (2019) 570-577.
[103] M. Pepe, R.D. Toledo Filho, E.A.B. Koenders, E. Martinelli, Alternative processing procedures for recycled aggregates in structural concrete, Constr Build Mater 69 (2014) 124-132.
[104] R. Jin, B. Li, S. Wang, O. Tsioulou, D. Wanatowski, A. Elamin, Experimental Investigation of Properties of Concrete Containing Recycled Construction Wastes, Int. J. Civ. Eng. (16(11)) (2018) 1621-1633.
[105] M. Chakradhara Rao, Properties of recycled aggregate and recycled aggregate concrete: effect of parent concrete, Asian J. Civ. Eng. 19(1) (2018) 103-110.
[106] S.C. Kou, C.S. Poon, Effect of the quality of parent concrete on the properties of high performance recycled aggregate concrete, Constr Build Mater 77 (2015) 501-508.
[107] S. Lotfi, P. Rem, J. Deja, R. Mróz, An experimental study on the relation between input variables and output quality of a new concrete recycling process, Constr Build Mater 137 (2017) 128-140.
[108] R. Tanaka, Z.L. Cui, M. Kitatsuji, The research existing condition and application of solid waste disposal in Japan, Sichuan Daxue Xuebao (Gongcheng Kexue Ban) 41(SUPPL.) (2009) 62-69.
[109] M. Baena, L. Torres, A. Turon, M. Llorens, C. Barris, Bond behaviour between recycled aggregate concrete and glass fibre reinforced polymer bars, Constr Build Mater 106 (2016) 449-460.
[110] A. Gonzalez-Corominas, M. Etxeberria, Effects of using recycled concrete aggregates on the shrinkage of high performance concrete, Constr Build Mater 115 (2016) 32-41.

[111] F. Aslani, G. Ma, D.L. Yim Wan, G. Muselin, Development of high-performance self-compacting concrete using waste recycled concrete aggregates and rubber granules, J. Clean. Prod. 182 (2018) 553-566.
[112] B. Yan, L. Huang, L. Yan, C. Gao, B. Kasal, Behavior of flax FRP tube encased recycled aggregate concrete with clay brick aggregate, Constr Build Mater 136 (2017) 265-276.
[113] A. Gonzalez-Corominas, M. Etxeberria, I. Fernandez, Structural behaviour of prestressed concrete sleepers produced with high performance recycled aggregate concrete, Mater Struct 50(1) (2017).
[114] G.A. Blengini, E. Garbarino, Integrated life cycle management of aggregates quarrying, processing and recycling: Definition of a common LCA methodology in the SARMa project, Int. J. Sustainable Soc. 3(3) (2011) 327-344.
[115] G.M. Cuenca-Moyano, S. Zanni, A. Bonoli, I. Valverde-Palacios, Development of the life cycle inventory of masonry mortar made of natural and recycled aggregates, J. Clean. Prod. 140 (2017) 1272-1286.
[116] T. Ding, J. Xiao, V.W.Y. Tam, A closed-loop life cycle assessment of recycled aggregate concrete utilization in China, Waste Manage. 56 (2016) 367-375.
[117] F. Colangelo, A. Forcina, I. Farina, A. Petrillo, Life Cycle Assessment (LCA) of different kinds of concrete containing waste for sustainable construction, Buildings 8(5) (2018).
[118] A. Di Maria, J. Eyckmans, K. Van Acker, Downcycling versus recycling of construction and demolition waste: Combining LCA and LCC to support sustainable policy making, Waste Manage. 75 (2018) 3-21.
[119] P. Saravanakumar, G. Dhinakaran, Durability aspects of HVFA-based recycled aggregate concrete, Mag Concr Res 66(4) (2014) 186-195.
[120] A. Baradaran-Nasiri, M. Nematzadeh, The effect of elevated temperatures on the mechanical properties of concrete with fine recycled refractory brick aggregate and aluminate cement, Constr Build Mater 147 (2017) 865-875.
[121] H. Elçi, Utilisation of crushed floor and wall tile wastes as aggregate in concrete production, J. Clean. Prod. 112 (2016) 742-752.
[122] J.S. Costa, C.A. Martins, J.B. Baldo, Masonry mortar containing mixed recycled aggregates from the traditional ceramic industry, InterCeram 62(1) (2013) 30-36.
[123] A. Akbarnezhad, K.C.G. Ong, C.T. Tam, M.H. Zhang, Effects of the parent concrete properties and crushing procedure on the properties of coarse recycled concrete aggregates, J Mater Civ Eng 25(12) (2013) 1795-1802.
[124] M. Pepe, E.A.B. Koenders, C. Faella, E. Martinelli, Structural concrete made with recycled aggregates: Hydration process and compressive strength models, Mech Res Commun 58 (2014) 139-145.
[125] P. Saravanakumar, Strength and durability studies on geopolymer recycled aggregate concrete, Int. J. Eng. Technol. 7(2) (2018) 370-375.
[126] R. Jin, B. Li, T. Zhou, D. Wanatowski, P. Piroozfar, An empirical study of perceptions towards construction and demolition waste recycling and reuse in China, Resour. Conserv. Recycl. 126 (2017) 86-98.
[127] W. Li, L. Cai, Y. Wu, Q. Liu, H. Yu, C. Zhang, Assessing recycled pavement concrete mechanical properties under joint action of freezing and fatigue via RSM, Constr Build Mater 164 (2018) 1-11.
[128] F. Liu, L.Y. Meng, G.F. Ning, L.J. Li, Fatigue performance of rubber-modified recycled aggregate concrete (RRAC) for pavement, Constr Build Mater 95 (2015) 207-217.
[129] Q. Peng, L. Wang, Q. Lu, Influence of recycled coarse aggregate replacement percentage on fatigue performance of recycled aggregate concrete, Constr Build Mater 169 (2018) 347-353.
[130] C. Thomas, I. Sosa, J. Setién, J.A. Polanco, A.I. Cimentada, Evaluation of the fatigue behavior of recycled aggregate concrete, J. Clean. Prod. 65 (2014) 397-405.
[131] R. Jin, Q. Chen, An Overview of Concrete Recycling Legislation and Practice in the United States, J Constr Eng Manage in Press, DOI: 10.1061/(ASCE)CO.1943-7862.0001630 (2018).
[132] Y. Xu, Wu, P., The Application of Recycled Aggregate Concrete in Pavement, Scholar's Press2017.
[133] N.D. Oikonomou, Recycled concrete aggregates, Cem Concr Compos 27(2) (2005) 315-318.
[134] C. Meyer, The greening of the concrete industry, Cem Concr Compos 31(8) (2009) 601-605.
[135] Y. Koshiro, K. Ichise, Application of entire concrete waste reuse model to produce recycled aggregate class H, Constr Build Mater 67(PART C) (2014) 308-314.
[136] V.W.Y. Tam, Economic comparison of concrete recycling: A case study approach, Resour. Conserv. Recycl. 52(5) (2008) 821-828.
[137] J.M.F. Mendoza, F. D'Aponte, D. Gualtieri, A. Azapagic, Disposable baby diapers: Life cycle costs, eco-efficiency and circular economy, J. Clean. Prod. 211 (2019) 455-467.
[138] H. Hou, S. Shao, Y. Zhang, H. Kang, C. Qin, X. Sun, S. Zhang, Life cycle assessment of sea cucumber production: A case study, China, J. Clean. Prod. 213 (2019) 158-164.

[139] A. Riaz, G. Zahedi, J.J. Klemeš, A review of cleaner production methods for the manufacture of methanol, J. Clean. Prod. 57 (2013) 19-37.
[140] G. Dobbelaere, J. de Brito, L. Evangelista, Definition of an equivalent functional unit for structural concrete incorporating recycled aggregates, Eng. Struct. 122 (2016) 196-208.
[141] B. Estanqueiro, J. Dinis Silvestre, J. de Brito, M. Duarte Pinheiro, Environmental life cycle assessment of coarse natural and recycled aggregates for concrete, Eur. J. Environ. Civ. Eng. 22(4) (2018) 429-449.
[142] E. Nazarimofrad, F.U.A. Shaikh, M. Nili, Effects of steel fibre and silica fume on impact behaviour of recycled aggregate concrete, J. Sustain. Cem. Based Mater. 6(1) (2017) 54-68.
[143] A. Gholampour, T. Ozbakkaloglu, Time-dependent and long-term mechanical properties of concretes incorporating different grades of coarse recycled concrete aggregates, Eng. Struct. 157 (2018) 224-234.
[144] Japanese Industrial Standards, Recycled concrete using recycled aggregate class H: JIS A 5021. Japanese Standards Association,Tokyo, Japan., (2005).
[145] Japanese Industrial Standards, Recycled concrete using recycled aggregate class L: JIS A 5023. Japanese Standards Association, Tokyo, Japan., (2006).
[146] H. Hartman, Brighton Waste House. https://www.architectsjournal.co.uk/buildings/brighton-waste-house/8666191.article. Accessed on 4 November 2018., (2014).
[147] R. Jin, Y.T. Chen, A. Elamin, D. Wanatowski, Y. Yu, Investigations on Properties of Recycled Aggregate Concrete Made from Different Construction Debris Sources, DII-2016 Conference on Infrastructure Development and Investment Strategies for Africa: Achieving Solutions for Renewable Energy and Sustainable Development (2016).
[148] J. de Brito, N. Saikia, Recycled Aggregate in Concrete: Use of Industrial, Construction and Demolition Waste, Springer London2012.
[149] F. Kleemann, H. Lehner, A. Szczypińska, J. Lederer, J. Fellner, Using change detection data to assess amount and composition of demolition waste from buildings in Vienna, Resour. Conserv. Recycl. 123 (2017) 37-46.
[150] R.K.D. OBE, J. de Brito, R.V. Silva, C.Q. Lye, Sustainable Construction Materials: Recycled Aggregates, Elsevier Science2019.
[151] S.O. Ajayi, L.O. Oyedele, M. Bilal, O.O. Akinade, H.A. Alaka, H.A. Owolabi, K.O. Kadiri, Waste effectiveness of the construction industry: Understanding the impediments and requisites for improvements, Resour. Conserv. Recycl. 102 (2015) 101-112.
[152] J. Xiao, Recycled Aggregate Concrete Structures, Springer Berlin Heidelberg2017.
[153] M. Bilal, L.O. Oyedele, O.O. Akinade, S.O. Ajayi, H.A. Alaka, H.A. Owolabi, J. Qadir, M. Pasha, S.A. Bello, Big data architecture for construction waste analytics (CWA): A conceptual framework, J. Build. Eng. 6 (2016) 144-156.
[154] R. Jin, L. Yan, A.B.O. Soboyejo, L. Huang, B. Kasal, Multivariate regression models in estimating the behavior of FRP tube encased recycled aggregate concrete, Constr Build Mater (2018).